CORONERS ACT, 1975 AS AMENDED

SOUTH *AUSTRALIA*

FINDING OF INQUEST

An Inquest taken on behalf of our Sovereign Lady the Queen at Adelaide and Whyalla in the State of South Australia, and Ada, Oklahoma and New York City, New York in the United States of America, on the 22nd July to 5th August 2002, the 26th August to 3rd October 2002, the 23rd to 30th October 2002, the 11th November to 24th December 2002, the 3rd, 29th and 30th days of January 2003, the 14th and 28th days of February 2003 and the 24th day of July 2003, before Wayne Cromwell Chivell, a Coroner for the said State, concerning the deaths of Benjamin Kurt Mackiewicz, Joan Elizabeth Gibbons, Teresa Viola Pawlik, Wendy Ruth Olsen, Peter Desmond Olsen, Neil Marshall, Richard Deegan and the disappearance of Christopher James Schuppan.

I, the said Coroner, do find that:

- *Benjamin Kurt Mackiewicz, aged 21 years, late of 2/18 Kent Road, Keswick, died in Spencer Gulf in the State of South Australia on the 31st day of May, 2000. I find that the cause of death was salt water drowning;*

- *Joan Elizabeth Gibbons, aged 66 years, late of 13 Lee Street, Whyalla, died in Spencer Gulf in the State of South Australia on the 31st day of May, 2000. I find that the cause of death was multiple injuries including flail chest;*

- *Teresa Viola Pawlik, aged 55 years, late of 42 Wainwright Street, Whyalla, died in Spencer Gulf in the State of South Australia on the 31st day of May, 2000. I find that the cause of death was salt water drowning;*

(Signed)

- *Wendy Ruth Olsen, aged 43 years, late of Mangalo, Cleve, died in Spencer Gulf in the State of South Australia on the 31st day of May, 2000. I find that the cause of death was salt water drowning;*

- *Peter Desmond Olsen, aged 45 years, late of Mangalo, Cleve, died in Spencer Gulf in the State of South Australia on the 31st day of May, 2000. I find that the cause of death was salt water drowning;*

- *Neil Marshall, aged 56 years, late of 2 Herbert Street, Newton, New South Wales, died in Spencer Gulf in the State of South Australia on the 31st day of May, 2000. I find that the cause of death was salt water drowning;*

- *Richard Deegan, aged 44 years, late of 16 Montrose Street, Netherby, died in Spencer Gulf in the State of South Australia on the 31st day of May, 2000. I find that the cause of death was salt water drowning;*

- *Christopher James Schuppan, aged 39 years, late of 8 Mildred Street, Whyalla Stuart, died in Spencer Gulf in the State of South Australia on the 31st day of May, 2000. The cause of death has not been determined.*

(Signed)

FINDING OF INQUEST

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Executive Summary

At 7:01:14pm on Wednesday 31 May 2000, a Mayday call was received at Adelaide Flight Information Service. The call came from Mr Ben Mackiewicz, the pilot of a Piper Navajo Chieftain Aircraft, registration number VH-MZK, owned by Whyalla Airlines. The aircraft was in the course of Flight 904 from Adelaide to Whyalla, South Australia, with eight persons on board. Mr Mackiewicz advised that they were 'about one five miles off the coast of Whyalla on the Gibon-Whyalla track'. The last radio transmission from MZK was at 7:04:20pm. At about 7:06pm, the crew of another aircraft heard a signal from an Emergency Locator Transmitter which lasted for about 20 seconds.

A very substantial search and rescue effort commenced under the supervision of Australian Search and Rescue, with South Australia Police coordinating the surface search. A large number of aircraft, marine vessels and land-based vehicles were utilised during the search, including large numbers of volunteers. All searched tirelessly throughout the night.

At 12:41am, the body of Mrs Wendy Olsen was found floating in the water, and the body of her husband, Mr Peter Olsen, was found nearby at 12:51am. A third body, which I find was that of Mr Christopher Schuppan, was seen at around the same time, but it disappeared from view, and has never been recovered.

MZK was eventually located on Monday 5 June 2000, lying on the sea bed. The bodies of Mr Ben Mackiewicz, Mrs Joan Gibbons, Mrs Teresa Pawlik, Mr Neil Marshall and Mr Richard Deegan were recovered from the wreckage. Post mortem examinations established that Mr Mackiewicz, Mr Olsen, Mrs Olsen, Mrs Pawlik, Mr Marshall and Mr Deegan all died as a result of salt water drowning. Mrs Gibbons died as a result of 'multiple injuries including flail chest'. I have not been able to determine the precise cause of Mr Schuppan's death.

The substantial damage suffered by MZK when it impacted the water, the sudden inrush of cold water at high velocity, the sudden loss of visibility, the injuries suffered by some of the passengers, and the gasp reflex phenomenon known as 'cold shock' leading to aspiration of water or laryngeal spasm, would have collectively led to instant incapacitation and rapid drowning. It is very unlikely that any of the occupants of MZK, including Mr and Mrs Olsen and Mr Schuppan, survived the impact.

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On the basis that none of those on board MZK survived the impact, it was not necessary to assess the quality of the search and rescue operation except in the sense that it forms part of the surrounding circumstances. However, the evidence establishes that the operation was conducted with a high degree of professionalism and skill, and those involved should be commended for their efforts.

An examination of the wreckage by the Australian Transport Safety Bureau (ATSB) established that the left engine of MZK had suffered a total fracture of the crankshaft, and the right engine had suffered a holed No.6 piston due to melting of the piston material.

The final ATSB report, published on 19 December 2001, attributed the fractured crankshaft in the left engine to fatigue, initiated by thermal cracking due to failure of the No.6 connecting rod bearing insert causing rubbing on the journal surface of the crankshaft. This failure was attributed to 'high bearing loads created by lead oxybromide deposit-induced preignition', and 'lowered bearing insert retention forces associated with the inclusion of an anti-galling compound between the bearing inserts and the bearings'.

The ATSB postulated that the bearings in the left engine began failing much earlier than 31 May 2000, so that at a time approximately 50 flights before that, thermal cracks began forming on the journal surface of the crankshaft, creating a weakness which led to the initiation of a fatigue crack which 'grew' over the next 50 flights, and eventually fractured the crankshaft completely at around 1837 or 1838 during Flight 904. It was suggested that the two pieces of the crankshaft remained 'dogged' together, allowing the engine to continue running until 1847:15 when the two sections parted and the engine ceased functioning.

The failure of the right engine was caused by a holed No.6 piston due to melting of the piston material. The ATSB postulated that when the left engine stopped at 1847:15, Mr Mackiewicz increased the engine power settings on the right engine to an inappropriate extent ('overboosting the engine') until, at about 1858 to 1900, detonation holed the piston and the right engine also failed.

To that extent, the ATSB argued that the two engine failures were 'dependent' in the sense that the failure of the left engine was causally linked to the failure of the right engine.

Evidence of material defects in crankshafts in Textron Lycoming engines, the type fitted to MZK, did not begin emerging until a Special Advisory Bulletin was issued on 9 November 2000, although similar failures had been noted in Teledyne Continental engines, the brand

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fitted to Cessna aircraft among others, as early as April 2000. The Civil Aviation Safety Authority (CASA) was advised that no Australian aircraft were affected by the 9 November 2000 Special Advisory Bulletin. On 1 February 2002, Textron Lycoming recalled about 400 engines, including one fitted to an identical aircraft to MZK, at around the same time the left engine was fitted to MZK. More extensive recalls were made on 16 August 2002 and 16 September 2002. Included among the approximately 3,000 engines on the 16 September 2002 list was the left engine in MZK. Each of these recalls was accompanied by a Mandatory Service Bulletin issued by Textron Lycoming which stated that the cause of the crankshaft failures was 'material related'.

On 14 December 2001, only five days before the ATSB final report was published, the right engine in an aircraft identical to MZK failed. Upon inspection of the engine, it was established that the crankshaft had fractured, and the appearance of the fracture was strikingly similar to that of MZK's left engine crankshaft. The ATSB did not examine the fracture in detail, so the aircraft owner commissioned an examination by an engineer who concluded that the failure was caused by a material flaw, and not by thermal cracking.

A scientific investigation conducted for this inquiry has thrown doubt on a number of ATSB conclusions:

- Professor King, an expert in chemical engineering and Dr Zockel, an expert in mechanical engineering, both agreed with the ATSB that the damage to the right engine was due to end gas detonation;

- Professor King concluded that there was considerable doubt about the ATSB conclusion that lead oxybromides were present in sufficient quantity to be a significant factor in the failure of the left engine;

- Dr Zockel concluded that the damage to the left crankshaft was not caused during the combustion stroke of the engine and so abnormal combustion was irrelevant anyway;

- Dr Zockel also concluded that the failure of the left crankshaft was not caused by bearing failure or thermal cracking as suggested by the ATSB;

- Dr Powell and Mr McLean, both experts in metallurgy, found iron oxide inclusions at the nearby No.5 journal of the left crankshaft of sufficient size to constitute a material defect capable of affecting the tensile and torsional strength of the crankshaft. Although similar inclusions were not found at the fracture site, they could have been lost during the fracture process;

(Signed)

- Mr Braly, an aeronautical engineer, aviator and manufacturer of aircraft components, also disputed that lead oxybromides were relevant to the failure of MZK's left engine, that the crankshaft could have remained 'dogged' as the ATSB suggested, that the aircraft could have maintained 167 knots groundspeed on one engine after 1847:15, and hence that the left engine failed first. He argued that the right engine suffered a partial loss of power at 1847:15, and that it was not until after 1858 or so that the left engine failed;

- Mr Braly also said that the mixture settings adopted by Whyalla Airlines for the climb phase of flight were too lean and these settings may have caused or exacerbated the damage to the right engine;

- Mr Hood, a metallurgist with McSwain Engineering Inc. in the United States of America also confirmed that the left engine crankshaft in MZK did not fail due to thermal cracking initiated fatigue fracture, that bearing failure was not relevant, and that the crankshaft failure was due to a 'manufacturing-related material condition'. Like Dr Powell and Mr McLean, they were unable to identify an inclusion in the metal at the fracture site, but he found a 'pocket' there, from where an inclusion may have fallen during the fracture process.

On the basis of the evidence presented at the inquest, I reached the following conclusions about how this tragedy occurred:

- It is possible (but not capable of proof) that the No.6 piston in the right engine of MZK was damaged during the takeoff and climb of Flight 904. It is very unlikely that damage occurred during the cruise phase;

- The right engine began running roughly and showing signs of end gas detonation damage at around 1837:41. Mr Mackiewicz reduced power on that engine at 1847:15 to protect it, causing a yaw to the right and reduction in groundspeed to 167 knots. He increased the RPM on the left engine to 2,400 to compensate. This was not 'overboosting' the engine;

- The crankshaft in the left engine failed at 1858:30 causing immediate cessation of function;

- Mr Mackiewicz may have tried to increase power on the right engine again after the left engine failed completely, but this would have not produced enough power to maintain altitude;

- The cause of the fracture of the left crankshaft was a fatigue crack, initiated from a subsurface defect in the steel as a result of a flaw in the manufacturing process, which created a point of weakness from which fatigue cracking radiated outwards over the ensuing 50 to 70 flights until it finally fractured through at around 1858:30 on 31 May 2000 causing immediate cessation of functioning;

- The cause of the failure of the right engine was end gas detonation damage to the No.6 piston, not due to 'overboosting' but possibly due to detonation during the 'climb' phase of Flight 904 when the mixture settings (specified in the Whyalla Airlines Operations Manual) were unduly lean and were likely to create unduly high peak cylinder pressures.

In forming those conclusions, a number of issues were identified at the inquest and considered. They assisted me to reach these conclusions in the following way:

- It is very unlikely that MZK would have been capable of maintaining a groundspeed of 167 knots in those conditions after 1847:15 if, as the ATSB argued, one engine was completely inoperative;

- Even if the aircraft was so capable, to achieve that groundspeed in those conditions, would have required absolutely maximum power on one engine, which was completely unnecessary since the aircraft was quite capable of maintaining altitude at a lower groundspeed on one engine at lower power settings, without putting the engine at risk;

- If Mr Mackiewicz had overboosted the engine, it is more likely that it would have been operating at 2,575 RPM (maximum) rather than 2,400 RPM detected by the ATSB;

- It is very unlikely that Mr Mackiewicz would have commenced his descent into Whyalla at 1855:54, and advised Adelaide Flight Information Service that he was expecting to arrive on time, if he was operating on only one engine at absolutely maximum power and was worried about maintaining altitude;

- Mr Mackiewicz made a number of radio transmissions after 1847:15, and as late as 1856:03 he was reporting his position without apparent concern. It is almost inconceivable that he would not have issued a Pan (distress) call at that point if he had completely lost one engine and was worried about maintaining altitude;

(Signed)

- It is highly unlikely that the bearings in the left engine failed long before 31 May 2000, to the extent that they could cause thermal cracks in the crankshaft and initiate the fatigue fracture 50 to 70 flights before Flight 904, and yet no sign of bearing damage, particularly metal particles in the oil, was noted in any of the services performed on the engine in the meantime;

- I have been informed that there have been a total of more than fifteen crankshaft failures in Textron Lycoming engines since this incident. Information about many of them is meagre, but a material defect has been confirmed by the United States authorities in seven cases, and suspected as the cause in the rest. This is the only case in which a different explanation for the crankshaft failure has been offered.

On the basis of these findings, I have made recommendations pursuant to section 25(2) of the Coroners Act, 1975, in the following areas:

- Pilot Operating Handbooks and Operators Manuals.

- International communication between regulators.

- On-Board Recorders.

- Self-deploying Emergency Locator Transmitters.

- Lifejackets.

(Signed)

1. Introduction

1.1. At 1901:14 (7:01:14pm) Central Standard Time, (incorrectly recorded in the ATSB report, Exhibit C97, as 1901:10) on Wednesday 31 May 2000, a radio message was received at the Adelaide Flight Information Service ('FIS'):

> 'ADELAIDE ADELAIDE THIS IS MAYDAY MAYDAY MAYDAY MAYDAY MZK HAS EXPERIENCED TWO ENGINE FAILURES WE'LL BE UM LANDING WE'RE GOING TO HAVE TO DITCH WE'RE TRYING TO MAKE WHYALLA AT THE MOMENT WE'VE GOT NO ENGINES SO WE'LL BE DITCHING WE HAVE EIGHT POB I REPEAT AGAIN EIGHT POB AND AH MOST LIKELY WE'RE CURRENTLY AH ABOUT ONE FIVE MILES OFF THE COAST OF WHYALLA ON THE GIBON WHYALLA TRACK REQUEST SOMEONE COME OUT AND HELP US PLEASE.' (Exhibit C98a)

1.2. MZK was a Piper Navajo Chieftain aircraft (VH-MZK) operated by Whyalla Airlines. It was engaged in Regular Passenger Transport ('RPT'), Flight 904 from Adelaide to Whyalla. There were eight persons on board ('POB') including the pilot, Mr Ben Mackiewicz. The passengers were:

- Joan Elizabeth Gibbons, 66 years, of Whyalla, South Australia
- Teresa Viola Pawlik, 55 years, of Whyalla, South Australia
- Wendy Ruth Olsen, 43 years, of Cleve, South Australia
- Peter Desmond Olsen, 45 years, of Cleve, South Australia
- Neil Marshall, 56 years, of Newtown, New South Wales
- Richard Deegan, 44 years, of Netherby, South Australia
- Christopher Schuppan, 39 years, of Whyalla, South Australia

1.3. The aircraft had departed Adelaide at 6:23pm. Radio communication between Mr Mackiewicz and various agencies during the journey had been entirely normal and had given no indication of trouble.

1.4. To describe what happened during Flight 904, I have set out a step-by-step chronology of events as I have been able to ascertain them. This will give the reader an overview of what occurred during the flight leading up to the ditching in Spencer Gulf at about 7:06pm on 31 May 2000. I will analyse some of these events in greater detail later in these findings, because it was argued at various times during the inquest that each of these events had significance in explaining what may have occurred.

1.5. A basic outline of the journey is as follows:

Time	Event
1815	Scheduled departure time
1820:14	Pilot of MZK requests clearance to taxi
1821:46	MZK cleared for takeoff
1823:12	Pilot of MZK advised Adelaide Approach, aircraft passing 500 feet on climb. Propeller RPM 2,400. Rate of climb approximately 850 feet per minute.
1829:51	MZK reaches top of climb (6,000 feet). Groundspeed 152 knots.
1831:42	Adelaide Controller instructs pilot of MZK to track direct to Whyalla.
1833:01	Having levelled out MZK reaches maximum cruise speed of 183 knots at 5,955 feet.
1833:54	Pilot of MZK advises Melbourne Centre controller maintaining 6,000 feet. Propeller RPM 2,200.
1837:41	Groundspeed becomes variable and reduces to an average of approximately 176 knots over the ensuing ten minutes.
1847:15	MZK diverges right by 19°. Groundspeed reduces by approximately 10 knots. Altitude increased by approximately 100 feet. Prior to diversion, MZK had been on track towards the 'Gibon' waypoint. Following diversion, and after some correction, MZK continues on direct track to Whyalla.
1855:43	Pilot of MZK acknowledges advice from Melbourne Centre controller that radar services are terminated by saying 'goodday'. Propeller RPM 2,400.
1855:54	MZK at top of descent.
1856:03	Pilot of MZK advises Adelaide Flight Information Service aircraft 35 miles south-south-east of Whyalla, commencing descent from 6,000 feet, estimating Whyalla at 1908.
1858:30	Rate of descent increases from 400 feet per minute to 650 feet per minute.
1900:19	Last valid radar contact. MZK was at 4,260 feet, 25.8 nms from Whyalla, travelling at 153 knots groundspeed.
1901:14	Mayday transmission. Analysis of the signal indicated that the landing gear unsafe horn had activated. This would have activated if one or both throttle levers were reduced below approximately 12 inches manifold pressure with the landing gear retracted, or not down and locked.

(Signed)

Time	Event (cont)
1903:00	Pilot of MZK confirms that heading straight for Whyalla. Analysis of the signal discloses the stall warning horn had activated. This activates when the aircraft is approaching aerodynamic stall, and sounds about 4 – 10 knots before a stall actually occurs. Which is estimated at between 77 and 83 knots with zero flaps.
1904:08	Pilot of MZK advises currently 15 miles.
1904:20	Pilot of MZK acknowledges transmission from Adelaide Flight Service. Says 'MZK thanks'. Last recorded radio transmission from MZK.
1906:38 (approx)	Crew of VH-FMC hear signal of the type emitted by Emergency Location Transmitter (ELT). Lasts for about twenty seconds.

1.6. Radio transmissions subsequent to the Mayday call were as follows:

CST	FROM	TO	TEXT
19:01:46	AD FIS 4	MZK	MZK ROGER AD
19:01:56	MZK	AD FIS 4	CONTACT COMPANY TOO AS FAST AS POSSIBLE
19:02:00	AD FIS 4	MZK	MZK WILCO
19:02:12	AD FIS 4	ML CENTRE	AH MZK HAS CALLED MAYDAY INBOUND TO WHYALLA. CAN YOU STILL SEE HIM ON THE RADAR
19:02:14	AD FIS TL	AUSSAR	ANDREW IT'S TREVOR HART FROM AD I'VE GOT A MAYDAY CALL
19:02:18	ML CENTRE	AD FIS 4	AH NO I CAN'T AH
19:02:19	AUSSAR	AD FIS TL	OK
19:02:20	AD FIS TL	AUSSAR	MZK HE'S AN RPT CHIEFTAIN, AD FOR WHYALLA, HE'S GOT EIGHT PERSONS ON BOARD, HE'S 15 MILES OFF FROM WHYALLA, OFF THE COAST OF WHYALLA AND HE'S DITCHING
19:02:26	AD FIS 4	ML CENTRE	GIBON WHYALLA TRACK, NO WORRIES THANKS MATE. IF YOU COULD JUST FIND OUT LAST TIME YOU HAD HIM?
19:02:32	ML CENTRE	AD FIS 4	YEP
19:02:33	AD FIS 4	ML CENTRE	TA MATE
19:02:39	AD FIS 4	BROADCAST	ANY STATION READING AD THIS FREQUENCY IN THE WHYALLA AREA, OTHER THAT MZK
19:02:39	AD FIS TL	AUSSAR	HE'S LOST BOTH ENGINES, HE SAID BOTH ENGINES WERE STOPPED AND HE'S DITCHING, AND HE JUST WANTS SOMEONE TO GO OUT AND HELP HIM
19:02:45	AUSSAR	AD FIS TL	OK NO WORRIES

(Signed)

CST	FROM	TO	TEXT (cont)
19:02:47	AD FIS TL	AUSSAR	OK
19:02:47	AUSSAR	AD FIS TL	ALL RIGHT I'LL GET SOME HELICOPTERS…
19:02:49	AD FIS TL	AUSSAR	THANKYOU
19:02:50	AUSSAR	AD FIS TL	THANKS MATE
19:02:50	AD FIS TL	AUSSAR	BYE
19:02:53	AD FIS 4	MZK	MZK ARE YOU STILL HEADING STRAIGHT FOR WHYALLA OR ARE YOU HEADING FOR THE COAST
19:03:00	MZK	AD FIS 4	MZK HEADING STRAIGHT FOR WHYALLA STANDBY
19:03:03	AD FIS 4	MZK	ROGER
19:03:17	FMC	AD FIS 4	AD GOOD EVENING FMC WE'RE 60 MILES AH AD MAINTAINING F140 ESTIMATING PORT AUGUSTA AT AH 46
19:03:29	AD FIS 4	FMC	FMC ROGER I'VE GOT A MAYDAY CALL THIS FREQUENCY, MZK, HE IS 15 MILES S OF WHYALLA ON THE GIBON WHYALLA TRACK. REQUEST YOU DIVERT AND TRY TO BE OF ASSISTANCE PERHAPS IN LOCATING THE AIRCRAFT HE IS DITCHING 15 MILES WHYALLA ON THE GIBON WHYALLA TRACK
19:03:53	FMC	AD FIS 4	ROGER THAT FMC COPIED
19:04:08	MZK	AD FIS 4	MZK IS NOW CURRENTLY 15 MILES
19:04:12	AD FIS 4	MZK	MZK ROGER IF YOU LOSE CONTACT WITH US COULD YOU TRANSMIT THROUGH FMC WHO WILL REMAIN THIS FREQUENCY
19:04:20	MZK	AD FIS 4	MZK THANKS

Glossary:

MZK -	Mr Ben Mackiewicz
AD FIS 4 -	Adelaide Flight Information Service (Operator 4)
ML Centre -	Melbourne Centre
AusSAR -	Australian Search and Rescue (Canberra)
AD FIS TL -	Adelaide Flight Information Service (Team Leader)
FMC -	VH-FMC, Royal Flying Doctor Service Aircraft piloted by Gary Williams
Miles -	All distances are given in nautical miles in aviation, so I will adopt that terminology here.

(Exhibit C98a)

1.7. What is remarkable about those transmissions (both the written transcript and the audio recordings, Exhibits C96j and C96k) is the calmness and professionalism being displayed by the pilot in these circumstances of gravest emergency. There is no hint of panic in his voice, he responded appropriately to questions, and supplied information to the best of his ability. The extent and gravity of the emergency will be discussed later in these findings.

(Signed)

2. Search and Rescue Response

2.1. Adelaide FIS contacted Australian Search and Rescue (AusSAR) in Canberra and notified them of the emergency at 7:02:14pm. AusSAR immediately took control of the air search, and contacted SA Police (SAPOL) in order that 'surface assets' could be deployed. As things transpired, AusSAR remained in an overall coordinating role, and SAPOL assumed responsibility for the land and sea search (T501).

2.2. AusSAR contacted Lloyds Helicopter Group (Adelaide) and ascertained that the Bell Helicopter 'Rescue 51' was available and would respond immediately. Another helicopter, 'Rescue 52', was also available but its capability in the prevailing weather conditions was less, so it was effectively placed on standby.

2.3. As Mr Dunning, counsel for AusSAR, pointed out, all these steps were taken before MZK had ditched.

2.4. Mr Williams, the pilot of FMC, states that around 7:06pm he heard an emission from an Emergency Locator Transmitter ('ELT'). Unfortunately, the transmission only lasted for 10 - 20 seconds, not long enough for the ELT to be located using a 'homing pattern' (T419).

2.5. Mr Williams descended to 2000 feet. He noticed a flashing light, which was later identified as a navigation light at Yarraville Shoal (T417). He said that at 2000 feet, he was unable to see the surface of the water, although he could see the lights of Whyalla (T418). It was a moonless night and it was difficult to detect the horizon visually (T423).

2.6. Within minutes, as a result of an offer of assistance from the Royal Australian Air Force, a P3-C Orion (Mariner 85) commanded by Flight Lieutenant Paul Freeman was also dispatched to the scene.

2.7. It was recognised from the start that MZK did not carry lifejackets or a life-raft. The water temperature in the area was approximately 16°C, and hypothermia could have led to drowning within two to four hours if any survivors were not located quickly. From two to twelve hours after immersion at 15°C there is a 50% expectancy of death (National Search and Rescue Manual, Exhibit C114).

2.8. There was some controversy about Mr Mackiewicz's advice in the Mayday call at 7:01:14pm that they were 'currently about one five miles off the coast of Whyalla on the Gibon Whyalla track', and his call at 7:04:08 pm that 'MZK is now currently 15 miles'.

2.9. An estimated splash point was established at approximately 11 miles south east of Whyalla on the Adelaide-Whyalla track. This was relayed to FMC, Mariner 85 and Rescue 51.

2.10. Some parts of Mr Mackiewicz's radio transmissions were also heard on a private radio by Mr Ian Bull, who notified his friend Mrs Raelene Haynes, who is the radio operator for the Spencer Gulf and West Coast Prawn Fisheries Association, and also the Volunteer Search and Rescue Coordinator for the State Emergency Service and the Wallaroo section of the Australian Volunteer Coast Guard. On her own initiative, Mrs Haynes advised the prawning fleet by a broadcast on VHF channel 71 at 7:20pm. There were 39 prawn boats at sea that evening.

2.11. In addition to that, AusSAR issued a 'Mayday' distress alert to all ships in the vicinity and SAPOL did the same to volunteer agencies, port authorities and the fishing industry.

2.12. At about 7:30pm Mr Barry Ellis, the master of the prawn boat Orao, responded to Mrs Haynes' call, advising that he, and the skippers of the Seabelle, Roslyn Ann and Skandia had all pulled their nets and were on their way. They were 18 miles from the scene at that stage, and it would take them about two hours to get there (Exhibit C103, p2)

2.13. By 7:25pm, Mariner 85 was already in the area flying at 300 feet conducting what Flight Lieutenant Freeman described as a 'creeping line ahead search' along the track taken by MZK, using the Orion's landing lights to illuminate the sea surface (Exhibit C108, p3). FMC had moved to a higher altitude and continued to orbit the area in order to assist with communications.

2.14. Rescue 51 arrived at the search area at 7:50pm and commenced searching at 500 feet. Rescue 51 was very well-equipped for the task, having excellent communications, a homing device to track ELT's, Forward-Looking Infrared (FLIR) sensors, and a 'nightsun' light.

(Signed)

2.15. Once Rescue 51 arrived, Mariner 85 climbed to a higher position to continue searching.

2.16. Many of the witnesses spoke of the difficulties faced by the searchers in finding any survivors in the water. It was a dark, moonless night, so much so that the pilots were unable to see the surface of the water. Only the head of a survivor would show above the water, so the chances of an aircraft finding such a person, even at low altitude, were very small (see the evidence of Mr Young at T463).

2.17. At about 8:15pm, the Whyalla Air Sea Rescue Squadron vessel 'City of Whyalla' departed Whyalla heading for the Yarraville Shoal area, arriving at about 9:15pm (Exhibit C62a). At around the same time, the State Emergency Service vessel 'City of Port Pirie' departed Port Pirie and proceeded to the search area (Exhibit C139).

2.18. The prawn boat Orao arrived at Yarraville Shoal at about 9:30pm (Exhibit C163a). The evidence of Inspector Kameniar indicates that by then, there were six vessels searching in a northerly direction, 100 metres apart at 10 knots, from Yarraville Shoal (Exhibit C119b). There were other vessels searching south of the Shoal as well.

2.19. At 9:56pm, the search fleet were directed to consolidate at the Yarraville Shoal light and a fully coordinated search pattern was then established.

2.20. By this time, searches of the coastline as far south as Cowell on the western side of Spencer Gulf and Port Broughton on the eastern side had also commenced.

2.21. As I have already mentioned, the search area was designated and this is illustrated by the diagrams appended to Inspector Kameniar's statement (Exhibit C119b). The 'splash point' was estimated using information received from AusSAR about the movements of MZK, in particular its altitude, Mr Mackiewicz's information in the radio transmissions, and estimates based on flying experience about the probable rate of descent of an aircraft operating without engines. From this information, it was calculated that the most appropriate search area was between 15 and 9 miles from Whyalla, on the Adelaide-Whyalla track (making due allowances for navigational discrepancies). It was also considered possible that the pilot may have turned the aircraft into the wind before ditching, or that he may have headed to the Yarraville Shoal being the only light in the area.

(Signed)

2.22. At 10:59pm, a second RAAF P3C Orion, designated R251 was tasked to the area. This was far better equipped than the first Orion, having FLIR, illumination flares, and sophisticated electronic surveillance equipment. The RAAF also made a Blackhawk helicopter (Tester 913) available and it also took part in the search. The crew were equipped with 'Night Vision' goggles.

2.23. At 11:03pm, the crew of the prawn boat Nicole located an Emergency Position Indicating Radio Beacon ('EPIRB') in the water at a point about six miles south of the Yarraville Shoal light. It took some time to establish that the EPIRB was in fact a datum buoy dropped by a search aircraft some time earlier in order to ascertain tidal movements.

2.24. At 11:18pm, a can of Coca-Cola was also found by the crew of Nicole quite close to the point where the EPIRB was found. Nicole was still steaming north to Yarraville Shoal at the time.

2.25. As a result of these finds, the search vessels were formed into a line and searched south from Yarraville Shoal towards those positions.

2.26. At 11:41pm, a bag of netballs carrying the inscription 'Wendy Olsen for Kay' was located at a point north of where the Coca-Cola can was located. In fairly rapid succession, a piece of tan vinyl (12:14am), a piece of fibreglass (12:21am), a black leather folder containing airline tickets (12:33am), and a woollen seat cover (12:35am) were found in the same general area.

2.27. At 12:41am, the crew of the prawn boat Skandia found the body of a female person later identified as Mrs Wendy Olsen. The body was retrieved from the water.

2.28. At 12:51am, a male body, later identified as Mr Peter Olsen, was also located by the crew of the Skandia. This body was also retrieved.

2.29. Some of the crew of Skandia reported that they saw a third body in the water, but by the time Mr Olsen's body was retrieved, the third body had disappeared. The skipper, Mr Keith Montgomery was unsure if he saw a third body (T971), since his position did not afford him as good an opportunity to observe the water as was available to his crewmen. His brother Mr Brian Montgomery was 100% sure (T988), and the other crewman, Mr Niki Mislov was 90% sure. His slight doubts were engendered by the

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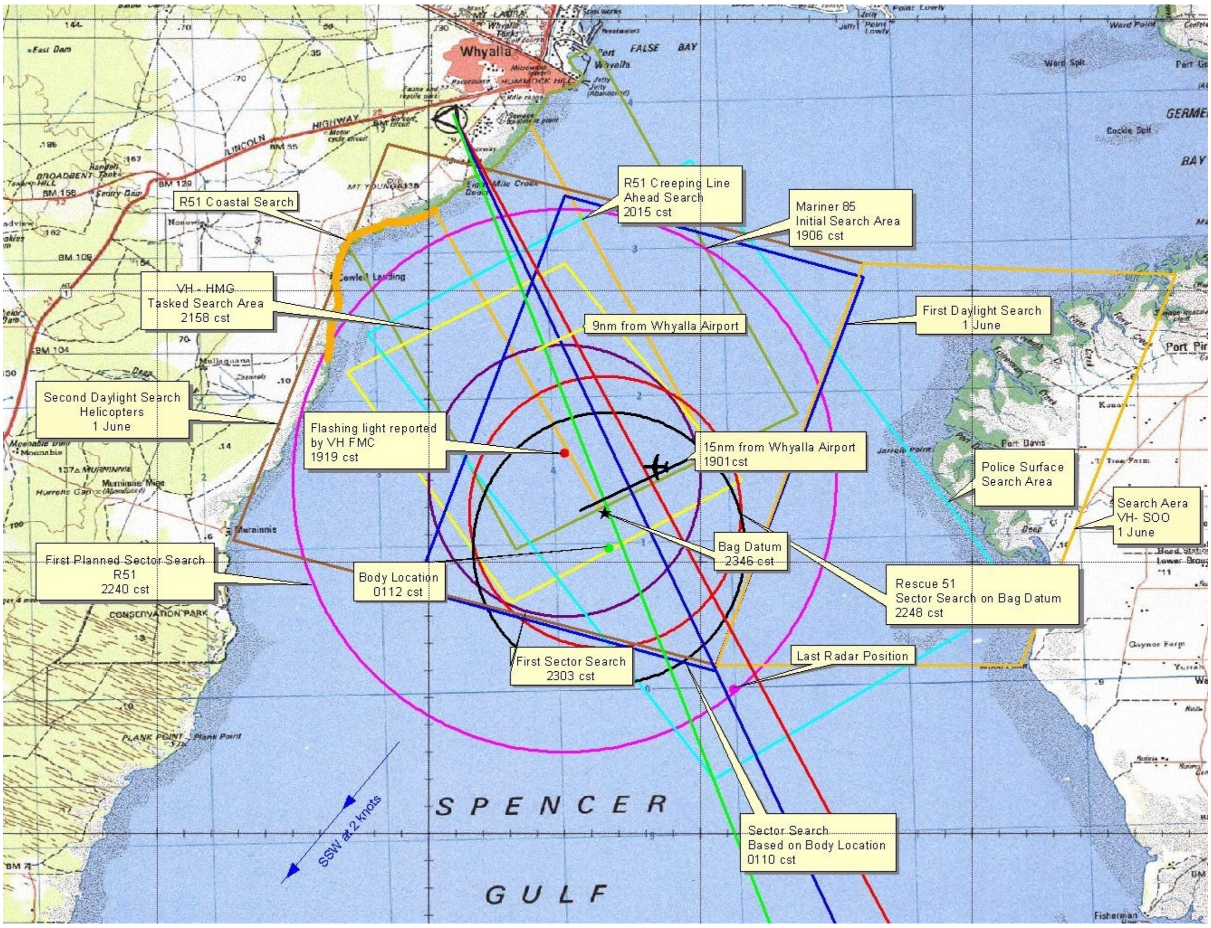
conditions (T1002). I find on the balance of probabilities that there was a third body. I find that this was the body of Mr Christopher Schuppan. It has never been recovered.

2.30. By the time the bodies of Mr and Mrs Olsen were located, there were more than 50 vessels, seven helicopters and two fixed wing aircraft engaged in the search. Even so, the conditions were extraordinarily difficult. Mr Keith Montgomery said that it was so dark that without lights, they would have been unable to see the surface of the water (T984). He said that had the bodies been 10 or 15 metres further away from the boat, he doubted that he would have seen them (T983).

2.31. In those circumstances, it was due to the alertness and professionalism of the searchers that they were able to find anything at all, let alone as much as they did. It is a credit to all involved that so much was achieved.

2.32. After the two bodies were recovered, the search continued and more pieces of wreckage were found. The boats continued performing line searches throughout the night and for the next several days.

2.33. An analysis of the maps and diagrams tendered (Exhibits C119a&b, C115) discloses that on several occasions the search vessels passed over the site where the wreckage was eventually discovered, but no sign of it was found, and no further bodies were found in the water. On the next page is a map (Exhibit C115, slide 14) which illustrates the many different search areas covered:



2.34. The air and surface searches continued throughout 1 June 2000. The AusSAR-directed air search was terminated at around 5:00pm that day. It was generally agreed that there was very little likelihood that there would be any survivors, and the prospects of making further significant sightings were also poor.

2.35. Responsibility for the ongoing search was transferred from AusSAR to SAPOL and accepted by SAPOL at 5:35pm on 1 June 2000.

2.36. On Friday 2 June 2000, the surface search continued on both sides of Spencer Gulf and at sea, looking mainly for oil slicks. This was continued on Saturday, and on Sunday 4 June, a crew from New South Wales Police arrived bringing side-scanning sonar equipment with them to assist with the search. This was fitted to the Fisheries SA vessel 'Tucana' and searching began that afternoon.

2.37. At about 2:30pm on Monday 5 June 2000, the Chief Pilot of Whyalla Airlines, Mr Kym Brougham was flying an aircraft over the search area and spotted what was later identified as an oil slick. He said that the sea surface was quite calm, as it often was at that time of day. He acknowledged the fact that the oil slick may not have been visible on previous days when the weather was rougher (T2574).

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2.38. This information was passed on to SAPOL, and the Tucana was directed to the coordinates provided by Mr Brougham. The side-scanning sonar was deployed and the wreckage was identified (see the statement of Mr Gryczeswski Exhibit C184a).

2.39. Divers from SAPOL Water Response Unit recovered five further bodies from the wreckage on 6 June 2000. The bodies were later identified as the pilot Ben Mackiewicz, and passengers Joan Gibbons, Teresa Pawlik, Neil Marshall and Richard Deegan. As I have said, no trace of Christopher Schuppan has ever been found.

2.40. The pilot Ben Mackiewicz was located in the pilot's seat, which is the front seat on the left hand side of the plane, with the seatbelt fastened. Joan Gibbons was located in her seat, in the fourth row from the front, on the right hand side of the aircraft, with the seatbelt still fastened. Teresa Pawlik was located floating against the roof of the fuselage, towards the front of the aircraft. Neil Marshall was located in his seat, second from the front on the right side, with the seatbelt still fastened. Richard Deegan was located on his hands and knees on the floor of the aircraft, at the rear of the cabin, facing the tail section (Exhibit C162a).

2.41. The wreckage was identified and mapped over the ensuing days until, on 9 June 2000, the wreckage was lifted onto the salvage vessel 'Andrew Wilson'. The remains of the aircraft were then handed over to the ATSB for scientific analysis.

2.42. Issues, Discussion and Conclusions

2.43. *Was there any confusion about the location of the 'splash point' as a result of Mr Mackiewicz's radio transmissions? Did any such confusion hamper the search and rescue effort?*

2.44. Mr Dunning, counsel for AusSAR submitted that the officials in charge of the air search correctly concluded that the initial call made by Mr Mackiewicz referred to the distance between the location of the aircraft and the coast of Whyalla, and that his second transmission referred to the distance to the Whyalla airport. Mr Kym Brougham submitted that in the second transmission Mr Mackiewicz was advising that the 'splash point' was 15 miles from Whyalla, and that he was not then advising them of his current location (T2569-2573).

2.45. It is clear from the evidence that there was an apparent inconsistency between the two transmissions made by Mr Mackiewicz. However, I do not consider that anything

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turns on the issue. It is apparent that the search was concentrated along the Adelaide-Whyalla track at a distance between 9 and 15 miles from Whyalla, which would have covered either interpretation of Mr Mackiewicz's transmissions, and due allowance was made for drifting with the current. It is also clear from the evidence that the search areas covered the actual splash point. In those circumstances, I do not consider that the radio transmissions made by Mr Mackiewicz hampered the search and rescue effort.

2.46. *Was the search and rescue operation timely, appropriately targeted and conducted with due professionalism and skill?*

2.47. On the totality of the evidence before me, I find that the search and rescue operation was indeed timely and appropriately targeted. As I have already pointed out, the search patterns adopted, as is illustrated by the maps and diagrams before me, passed over the actual splash point, where the wreckage was eventually located. Despite the fact that the conditions for search and rescue were extremely adverse, the location of articles from MZK, and then the location of the bodies of Mr and Mrs Olsen, occurred within hours. This was an extraordinary achievement, in my opinion, having regard to the evidence that it was so dark that, without lights, the searchers would have been unable to see the surface of the water from their boats.

2.48. It is necessary to mention that it is a matter of great credit to all of the volunteers that they went into action so quickly, as soon as the ditching became known. The prawn fishermen, in particular, immediately ceased their fishing activities and began steaming north to the search area. All participants, both volunteers and salaried personnel, should be commended for the dedication and professionalism shown throughout the search and rescue effort.

2.49. The search and rescue was a very extensive one, involving multiple resources in relation to air, sea and land searching. The deployment of a wide variety of resources in an urgent situation, particularly where civilian resources are involved, must inevitably involve some confusion and miscommunication. However, on the evidence before me, it seems that any such difficulties were kept to a minimum, and that the search and rescue coordinators from both AusSAR and SAPOL did a remarkable job in adverse conditions. I find that the search and rescue operation was conducted with a high degree of professionalism and skill.

(Signed)

3. Post-Mortem Investigations

3.1. Benjamin Kurt Mackiewicz

3.1.1. Dr J D Gilbert, Forensic Pathologist, performed a post-mortem examination on the body of Ben Mackiewicz at the Forensic Science Centre on 7 June 2000. Mr Mackiewicz was identified by Forensic Odontologist Dr Jane Taylor (Exhibit C4a). Dr Gilbert attributed Mr Mackiewicz's death to salt water drowning (Exhibit C164, p1).

3.1.2. Dr Gilbert noted a compound dislocation of the metatarso-phalangeal joint of Mr Mackiewicz's left big toe, the main joint at the base of the big toe (T1141). Dr Gilbert speculated that Mr Mackiewicz may have been exerting pressure on the left rudder pedal of the aircraft at the time of impact (T1141), although he was by no means sure of that suggestion in view of further cross-examination (T1157).

3.1.3. There is no suggestion that Mr Mackiewicz was affected by drugs or alcohol at the time of the ditching (Exhibit C164, p5).

3.2. Neil Marshall

3.2.1. Dr Gilbert also performed a post-mortem examination on the body of Neil Marshall at the Forensic Science Centre on 7 June 2000. Dr Jane Taylor also identified Mr Marshall odontologically (Exhibit C6a). Dr Gilbert attributed Mr Marshall's death to salt water drowning (Exhibit C164a, p1).

3.2.2. Dr Gilbert noted multiple fractures of Mr Marshall's ribs on both sides, fractures of the tibia and fibula on both sides and minor bruising on the right side of the scalp. He commented that none of these injuries would have been fatal, but would have prevented Mr Marshall from exiting the aircraft (Ex C164a, p4). He added that the head injury may have rendered Mr Marshall unconscious (T1145).

3.3. Richard Deegan

3.3.1. Dr R A James, Chief Forensic Pathologist, performed a post-mortem examination on the body of Richard Deegan at the Forensic Science Centre on 7 June 2000. Dr Taylor identified Mr Deegan odontologically (Exhibit C1a). Dr James attributed Mr Deegan's death to salt water drowning (Exhibit C167, p2).

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3.3.2. Dr James noted an abrasion on the point of the chin, and bruising to the lower left neck and below the right groin (Exhibit C167, p3). There were no fractured bones, and no damaged internal organs.

3.3.3. Dr James noted contusions (bruising) of the left temporal lobe of the brain, and evidence of haemorrhage in the region of the left basal nuclei. He commented that he did not believe that these injuries would have been fatal, but quite probably rendered Mr Deegan unconscious at the time of impact (T1183-84).

3.4. Joan Elizabeth Gibbons

3.4.1. Dr James performed a post-mortem examination on the body of Joan Gibbons at the Forensic Science Centre on 7 June 2000. Dr Taylor identified Mrs Gibbons odontologically (Exhibit C225a). Dr James diagnosed the cause of Mrs Gibbons' death as 'multiple injuries including flail chest' (Exhibit C167b, p2).

3.4.2. Dr James noted lacerations above the left eyebrow, bruising of the left cheek, lacerations down the midline of the chin, extensive bruising on the left side of the neck, on the lower abdomen and the left calf. All ribs were fractured on both sides both parasternally and laterally (flail chest), and the lungs had collapsed. There was no water in the airways.

3.4.3. Additionally, Mrs Gibbons had a fractured spine, pelvis, right tibia and fibula, left hand, left upper arm and larynx.

3.4.4. There were contusions to the lateral aspect of the left temporal lobe and the interior aspect of the left frontal lobe. Dr James said that these injuries would have been sufficient to render Mrs Gibbons unconscious upon impact. The chest injuries would have been fatal (T1186).

3.5. Teresa Viola Pawlik

3.5.1. Dr James performed a post-mortem examination on the body of Teresa Pawlik at the Forensic Science Centre on 8 June 2000. Mrs Pawlik was identified odontologically by Dr Taylor (Exhibit C17a). Dr James attributed Mrs Pawlik's death to salt water drowning (Exhibit C167d, p1).

3.5.2. Dr James noted a laceration on Mrs Pawlik's right shin, bruising on both shins, across the upper left thigh and on the left wrist. There was a fractured sternum but no other fractures. He noted obvious bruising of the left temple region, and this, coupled with the absence of swallowed water in the stomach, led him to suggest that Mrs Pawlik may have been unconscious upon impact (T1187).

3.6. Peter Desmond Olsen

3.6.1. Professor RW Byard, Forensic Pathologist, performed a post-mortem examination on the body of Peter Olsen at the Forensic Science Centre on 2 June 2000. Mr Olsen was identified visually by a near relative (Exhibit C12a, p1). Professor Byard diagnosed the cause of Mr Olsen's death as salt water drowning (Exhibit C9a, p2).

3.6.2. Professor Byard found 'minor' bruising of the face, scalp and forearm, fracture of the right arm (ulna), right femur and right ribs, fractures of the right orbit with subarachnoid haemorrhage of the brain, congestion and oedema of the lungs with bilateral pleural effusions and bone marrow and fat emboli. He also found white foam in the mouth and upper airway (Ex C9a p2).

3.6.3. Professor Byard commented in his report:

> 'Death is attributed to salt water drowning based on the presence of congestion and oedema of lungs with white foam within the upper airway. In addition, there were no lethal injuries identified. The presence of bone marrow and fat emboli in the lungs would be in keeping with survival for an unspecified time after the injuries were received. Given the relatively minor nature of the injuries, it is likely that the deceased survived the impact of the crash and succumbed to drowning. The presence of limb fractures and rib fractures would, however, have made swimming difficult. It is also possible given the presence of a fracture of the right orbital plate and diffuse subarachnoid haemorrhage that the conscious state of the deceased may have been impaired, or that he may even have been unconscious following the accident.' (Exhibit C9a, p3)

3.7. Wendy Ruth Olsen

3.7.1. Dr Gilbert performed a post-mortem examination on the body of Wendy Olsen at the Forensic Science Centre on 2 June 2000. Mrs Olsen was identified visually by a relative (Exhibit C16a, p1). Dr Gilbert diagnosed the cause of Mrs Olsen's death as salt water drowning (Exhibit C164b, p1).

3.7.2. Dr Gilbert found scattered bruising and abrasions of the head, right arm, upper left thigh and back, left leg and right leg. There were multiple fractures of the left ribs both anti-laterally and posteriorly, and a compound fracture of the right tibia. He found white froth at the lips consistent with inhalation of seawater. He also found 'widespread sloughing' of the skin of the upper body which he suggested may have been caused by contact with aviation fuel (Exhibit C164b, p2), hydraulic fluid or brake fluid (T1166).

3.7.3. Dr Gilbert said that the injuries sustained by Mrs Olsen were 'relatively minor and survivable' (T1148). However, her ability to swim or tread water would have been impaired by the rib and leg fractures.

3.7.4. Dr Gilbert had some difficulty explaining the fact that Mrs Olsen's jeans were found by the SAPOL divers attached to the right wing of the aircraft on the seabed (see the statement of Constable Brownridge, Exhibit C58a, p3). The jeans were relatively undamaged. There was some damage to the knee and shin areas, which would correspond with Mrs Olsen's leg injuries (Exhibit C164c). Dr Gilbert thought it was unlikely that Mrs Olsen would have removed the jeans manually after impact, in view of the leg injuries and other difficulties, and the lack of damage made it unlikely that they were torn off during impact (T1150). The issue remains a mystery.

3.7.5. Dr Gilbert thought that the bruising to Mrs Olsen's scalp (front and rear) was 'very minor'. He said that a loss of consciousness upon impact was 'possible but by no means certain' (T1153).

3.8. Christopher James Schuppan

3.8.1. I have already mentioned that Mr Schuppan's body has never been recovered. Two of the crewmen of the Skandia saw a third body in the water, and I have found that this was the body of Mr Schuppan. No specific injuries were noticed at that time.

3.8.2. It is not possible to find the precise cause of Mr Schuppan's death in view of that. In particular, it is not possible to find whether he survived the impact or not.

3.8.3. In those circumstances, I find that Mr Schuppan died from undetermined causes.

(Signed)

3.9. Survivability of Impact

I heard evidence from Dr Jeffrey Brock, who is a Consultant and Specialist Adviser in Aviation Medicine to the Australian Defence Force. He formerly served in the Australian Army, and holds the rank of Colonel. From 1995 to 1998 he was the Acting Director of Aviation Medicine for the Civil Aviation Safety Authority ('CASA'). Dr Brock has been trained in altitude medicine, extreme weather survival, aviation underwater escape, and has been an instructor in survival techniques on land and in the ocean. He has participated in numerous helicopter rescues at sea and subsequent resuscitation of survivors. He holds numerous specialist medical qualifications, and is a qualified Army pilot in both fixed wing and helicopter aircraft. Dr Brock is uniquely qualified to explain what happened when MZK ditched in Spencer Gulf on 31 May 2000.

3.10. Dr Brock said that it would have been 'exceptionally difficult' for the pilot of MZK to have ditched the aircraft in a completely level altitude, having regard to the darkness of the night, the lack of a visible horizon, the emergency situation, and the low speed which would have made the aircraft more difficult to handle (T1202). The ATSB examination of the wreckage indicated that the right wing struck the sea surface first. At that time, the aircraft was slightly nose-down, and wings-level or banked slightly right. The impact tore off the right wing and left a large hole in the right side of the fuselage. The aircraft would have slewed violently to the right, and when the front hit the water, it was severely deformed inwards. The cabin would have instantly filled with water. The impact, and the inrushing water, forced the doors, most windows, and the emergency escape hatch out of their frames. Both engines were torn off (Exhibit C97, p22).

3.11. The report of the ATSB (Exhibit C97) contains information about 13 instances where Piper Navajo and Piper Chieftain aircraft have ditched into water since 1984 (p128-9). Remarkably, in 10 of these instances, all on board survived. As to the other three, in one instance a passenger had a cardiac arrest, in the second instance, seven of the eight people on board were able to exit. In a third instance, the aircraft was substantially damaged, and the pilot, as here, was found deceased, still strapped in his seat.

3.12. Dr Brock said that the most significant factor which enabled survival in the other 10 cases was that the aircraft was ditched at the slowest possible speed, and was basically

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undamaged after ditching, thereby allowing it to float for a short period giving the occupants the opportunity to escape.

3.13. Once MZK was in the water, the visibility would have been zero, in other words, the occupants would not have been able to see a finger a few inches from their eyes. This, combined with the impact of the water swirling around, the cold temperature, and the loss of orientation due to interference with the vestibular mechanism in the inner ear, would have rendered the passengers almost helpless (T1202).

3.14. Dr Brock explained that the force of impact with the water would have been ‘very significant’. The forces involved caused significant injuries as the passengers ‘flailed’ about inside the cabin. Several had multiple rib fractures, which would have hindered them from holding their breath and extracting themselves. Similarly, the passengers with leg and pelvic fractures would have been impeded from escaping (T1203-4).

3.15. Dr Brock thought that all of the passengers would have suffered ‘concussion’, in other words their senses would have been stunned, and they probably suffered at least partial loss of consciousness, and total unconsciousness in several cases. In that case, they would have been unable to protect their airway, and drowning would have quickly ensued (Exhibit C168, p4).

3.16. ‘Cold Shock’

Dr Brock said:

> 'Once the aircraft struck the water, the deceleration forces caused structural deformation, some of which resulted in the avulsion of the right wing and opening-up of part of the right side of the aircraft. As the inertia of the aircraft ploughed the fuselage through the water and opened up the right side and cockpit area, there would have been a significant ingress of large volumes of swirling, cold water and very rapid sinking. This ingress would have caused injuries, initiated the “cold shock” phenomenon and prevented the escape of passengers.
>
> **Submersion and Cold Shock**
>
> Submersion in cold water can cause a complex response in humans. In some cases the exposure may be rapidly fatal due to the phenomenon of “cold shock” which is described in most reference texts of diving/sub-aquatic medicine. When a person is plunged into cold water such as in a ditching, there is an initial gasp reflex. If the victims sink so quickly or are confronted with such a forceful avalanche of water when this gasp reflex occurs, they commence uncontrollable hyperventilation (up to ten times the resting breathing rate) leading to aspiration of cold water through the nose and mouth. Aspiration of water into the airway (even a single mouthful is enough) is lethal because it

> causes asphyxia. Sometimes aspiration does not occur; instead laryngeal spasm causes asphyxia and leads to death. Pain associated with fractures of long bones or ribs increases the likelihood of hyperventilation and aspiration. In the event that an individual was not drowned or injured during the impact sequence, but remained strapped in their seat until the aircraft settled on the sea floor, it is improbable that the individual could breath-hold for sufficient time to clear an escape path and find their way to the surface.' (Exhibit C168, p4)

He said that the temperature of the water on this night (14-16°C) was sufficiently cold to induce this gasp reflex leading to rapid drowning (Exhibit C168, p5).

3.17. Dr Brock also pointed out that the impending ditching must have caused fear and apprehension to an extreme degree in both the pilot and passengers. This would have provoked extreme psychological responses including raised pulse, blood pressure, adrenaline levels and breathing rate. These responses alone may have been enough to incapacitate (T1210).

3.18. Dr Brock described the extreme disorientation this ditching would have engendered, so that it would have been difficult to appreciate which way was up. He also pointed to the difficulties the passengers would have encountered in undoing their seatbelts, disentangling themselves from the wreckage, debris and other passengers, locating an exit and then swimming almost 30 metres to the surface. He described how narrow and cramped the cabin of a Piper Navajo Chieftain is, (I noted this when inspecting a similar aircraft on 2 September 2002), and the cramped layout of the seats with substantial obstructions caused by the wing spars. He mentioned the smallness of the exits, and the other obstructions including those which may have been caused by an already unconscious or deceased fellow passenger. All of these factors would have mitigated against a successful escape (T1214-15). He said in relation to Mr and Mrs Olsen and Mr Schuppan:

> 'The discovery of five deceased occupants in the cabin (three still fastened to their seats) indicates that they had little or no opportunity to escape. The two victims located on the surface probably died in the aircraft cabin, came adrift from their seats and floated to the surface through the opening in the right side of the aircraft. Their injuries are such that it is unlikely that they could have survived the impact sequence and escaped successfully, only to perish later whilst on the surface.
>
> It is not possible to predict the fate of the missing occupant; however, given the nature of the injuries of the others, it is highly improbable that the missing occupant made a successful escape, only to perish later whilst waiting to be rescued. It is more likely that this occupant drowned in the cabin, then floated to the surface or was carried off by the prevailing current.' (Exhibit C168, p6)

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3.19. In relation to Mrs Olsen's jeans, Dr Brock said that it is most probable that they were removed forcibly due to fouling with the fuselage. He said that it is a 'fascinating phenomenon' in aircraft accidents for people to involuntarily lose their clothing. He thought it was improbable that Mrs Olsen removed them voluntarily either before or after the impact (T1223).

3.20. Dr Brock said that lifejackets are potentially valuable in aircraft accidents where passengers survive the ditching, but their availability in this case was unlikely to have changed the outcome in view of the injuries, the difficulties involved in putting them on, and the fact that they may have made egress from the aircraft even more difficult (T1224).

3.21. Dr Brock's conclusions were as follows:

> 'This was not a survivable accident for the occupants.
>
> The type of seat belts fitted to this aircraft did little to prevent serious injury or drowning.
>
> The seat arrangement (forward-facing) increased the likelihood of very rapid drowning because the occupants were facing in the direction of the violent ingress of water through the structural defect in the right side of the fuselage.
>
> Had the cabin integrity been preserved limiting the rapid ingress of cold water, the chances of a successful escape for some occupants would have improved. The disruption to the integrity of the cabin is probably the major factor contributing to their deaths because it permitted the rapid and lethal in-rush of cold water; it almost certainly caused injuries as well as allowing very rapid filling of the cabin and sinking. This is likely to have occurred in less than 45 seconds.
>
> The availability of life preservers or other individual flotation devices would not have altered the outcome in this accident.
>
> For some or all of the occupants to have had a reasonable chance of survival in this accident, there would need to have been rescue divers in the water at the time of the impact and very nearby, in order that they could commence immediate extrication of occupants from the aircraft as soon as it hit the water and sank. This was not possible or realistic given the rapid sequence of events.
>
> The occupants died from drowning, the effects of injuries or the interplay between them.
>
> The occupant injuries described in the post mortem reports are quite serious in a number of individuals, even more so in the context of this ditching. Four of the occupants had multiple rib fractures (potentially lethal in every case in the context of underwater escape, even without the addition of lower limb or other fractures); and another had a fractured sternum. Two occupants had no discernable injuries at all and no details are available on the missing occupant.

> It is my opinion that all occupants died very quickly (within seconds to a few minutes of submersing) from drowning and that the injuries sustained by them materially contributed to their inability to escape from the wreckage.
>
> The depth of water, darkness and water temperature materially increased the risk of drowning…….
>
> If there had been no injuries, would the outcome have been any different? It is difficult to be certain, but all the evidence seems to support the view that the ditching was violent. This also accounts for the recorded injuries and death of all on board. It is probable that the occupants were all "stunned" or "concussed" by the impact forces and the in-rush of water, and had too little time to recover, orient themselves and initiate escape because the aircraft was already sinking rapidly. The fact that at least two occupants had no obvious injuries adds some weight to the view that other factors had far more influence on the lack of survivability.
>
> In the final analysis, the contribution of any one of the **Survivability Aspects** discussed above (e.g visual conditions, impact injuries, submersion and cold shock, water temperature, etc…) was potentially lethal; however the cumulative effect from the presence of them all was more than additive. Rather, the interplay of them all produced a disproportionately high risk of death, possibly exponential. This made the likelihood of survival remote for any of the occupants.
>
> Given the seriousness of the aircraft emergency, the extremely limited time available to deal with this crisis and the prevailing environmental conditions at the time, the pilot performed remarkably well to ditch the aircraft the way that he did.'
>
> (Exhibit C168, p8-10)

3.22. Issues, Discussion and Conclusions

3.23. *What was the cause of death of each of the deceased?*

3.24. I accept the evidence of Drs Gilbert, James and Byard, and find that:

- Benjamin Kurt Mackiewicz died on 31 May 2000 as a result of salt water drowning;
- Wendy Ruth Olsen died on 31 May 2000 as a result of salt water drowning;
- Peter Desmond Olsen died on 31 May 2000 as a result of salt water drowning;
- Joan Elizabeth Gibbons died on 31 May 2000 as a result of multiple injuries including flail chest;
- Teresa Viola Pawlik died on 31 May 2000 as a result of salt water drowning;
- Neil Marshall died on 31 May 2000 as a result of salt water drowning;
- Richard Deegan died on 31 May 2000 as a result of salt water drowning;
- Christopher Schuppan died on 31 May 2000 as a result of undetermined causes.

(Signed)

3.25. *Did any of the occupants of MZK survive the impact with the water?*

3.26. I accept the evidence of Dr Brock, and find, on the balance of probabilities, that:

- All of the occupants of MZK died 'very quickly' when the aircraft impacted with the water;
- If any of the deceased did not die instantly, they were rendered unconscious or completely incapacitated either through cerebral concussion, 'cold shock' or both, to the extent that they were unable to protect their airway and died quickly through drowning;
- The serious injuries sustained by a number of the deceased would have substantially reduced their ability to escape from the wreckage, even if they did survive the impact.

3.27. *Would their chances of survival have been enhanced if they had been wearing lifejackets, or there were other floatation aids including a life-raft, available?*

3.28. Having regard to the conclusions outlined above, I do not consider that the wearing of lifejackets, or the presence of other floatation aids including a life-raft, would have materially improved the chances of survival for any of the occupants of MZK.

4. Whyalla Airlines

4.1. According to the final ATSB report, Exhibit C97, Whyalla Airlines Pty Ltd was incorporated in South Australia on 22 October 1987, and was issued with an Air Operators Certificate (AOC) on 24 January 1990. The AOC permitted regular passenger transport (RPT) services over various routes, including Adelaide to Whyalla, as well as charter operations.

4.2. On 27 March 1995, Whyalla Airlines was issued with a Certificate of Registration for VH-MZK. The aircraft had originally been built in the United States of America in 1981, and a Certificate of Airworthiness, which is normally issued around the time an aircraft is imported into Australia, was issued on 2 June 1988.

4.3. By 31 May 2000, Whyalla Airlines owned four Piper Chieftains and several other aircraft. It employed six pilots, including the Chief Pilot and one of the Founding Directors of the Company, Mr Kym Brougham. The other Founding Director was his brother, Mr Chris Brougham.

4.4. Mr Kym Brougham is a highly qualified and experienced pilot. He had accumulated approximately 10,000 hours flying experience by 31 May 2000. He has participated in national and international air races, and he is qualified as an aerobatics pilot as well. In 1995, CASA approved him as a 'Check and Training Pilot'.

4.5. Whyalla Airlines has had a troubled relationship with CASA over the years. A brief chronology of some of the relevant events is as follows:

- On 29 June 1997, MZK was landed in a paddock near Wudinna after running short of fuel. The pilot's licence was suspended and subsequently reinstated after an examination;
- After that incident CASA audited Whyalla Airlines and identified a substantial number of issues of concern;
- On 6 September 1997, Mr Kym Brougham was involved in an incident in which it was alleged that he failed to comply with Air Traffic Control instructions. CASA suspended his Check and Training Pilot approval and his Command Instrument Rating on 12 September 1997;

(Signed)

- On 27 October 1997, a report to the CASA Board identified a number of difficulties with Mr Kym Brougham, most of them related to his uncooperative and recalcitrant attitude. However, the ATSB report noted:

> 'The RPT operations of the company are of comparable safety of other LCRPT operators and better than some……
>
> Despite the administrative recalcitrance of the Chief Pilot, he provides additional training above the industry standard and spends considerable amount on ensuring the continuing airworthiness status of his aircraft. He is well regarded by his employees and is not regarded adversely by his industry peers. In short, he cannot reasonably be assessed as anti-safety, merely anti-establishment or anti-Authority.' (Exhibit C97, p92);

- On 26 December 1997, CASA cancelled Mr Brougham's Chief Pilot approval as well. Whyalla Airlines appealed against that decision. In the meantime, Mr David Usher, who at that time was also the company maintenance controller, was approved as Chief Pilot for three months;
- After a considerable amount of negotiation during 1998, Mr Brougham eventually passed a flight proficiency test and his Check and Training Pilot approval was restored on 19 November 1998;
- A number of further checks and inspections occurred during 1999 and in September 1999, the AOC was reviewed and reissued;
- On 26 October 1999, a major airworthiness audit of Whyalla Airlines was performed by CASA, a number of 'minor deficiencies' were identified and rectified;
- By April 2000, CASA's attitude towards Kym Brougham had changed. On a couple of occasions they had approved his application to act as Chief Pilot in the absence of Mr Usher until, on 10 April 2000, CASA approved his appointment as Chief Pilot 'during notified absences of the substantive chief pilot'. Exhibit C97 notes:

> 'CASA was satisfied that, from all of its observations and involvement with the Manager (Kym Brougham), he had the motivation, ability and intention to avoid the circumstances that led to his chief pilot cancellation and the threat to the company's AOC.' (Exhibit C97, p95);

(Signed)

- On 12 April 2000, the employment of Mr David Usher was terminated. Mr Usher had worked at Whyalla Airlines since its inception in 1990. Upon his termination, Mr Brougham resumed his position as Chief Pilot;
- Exhibit C97 further notes:

> 'CASA had advised the airline of its intention to conduct an annual periodic inspection in May 2000. However, other urgent tasks diverted staff resources within CASA and the inspection had not occurred by the time of the accident on 31 May 2000. (Only three of the seven CASA FOI positions in Adelaide were staffed at that time).' (Exhibit C97, p95)

4.6. Following the accident on 31 May 2000, CASA received 'some anonymous reports' which caused them to undertake a 'special audit' of Whyalla Airlines between 6 and 13 June 2000. The Managing Director, Mr Chris Brougham, had already decided to suspend all flight operations on 1 June 2000, the day after the accident (see Exhibit C74a, page 2).

4.7. Following the audit, CASA concluded that there were a number of issues which required further investigation:

- maintenance of accurate flight and duty records;
- compliance with the flight and duty provisions applicable to the company;
- company safety culture;
- keeping of fuel records, charter manifests; and
- flight crew instrument recency. (Exhibit C97, page 96)

4.8. On 10 June 2000, CASA suspended Whyalla Airlines' AOC pending further investigation, and this suspension was challenged by Whyalla Airlines in the Administrative Appeals Tribunal. On 31 July 2000, Whyalla Airlines voluntarily surrendered its AOC and has not operated since that time.

4.9. The ATSB final report, Exhibit C97, analysed the effectiveness of CASA's surveillance program in relation to Whyalla Airlines. CASA had developed an 'Aviation Safety Surveillance Program' (ASSP), in order to monitor whether airline operators and maintenance organisations were meeting their statutory obligations. The report states:

> 'The surveillance planning process was designed to assist in identifying those operators that had a relatively high safety risk and as such, to assist in determining local surveillance priorities.' (Exhibit C97, p97)

(Signed)

4.10. The ATSB report comments that their investigation did not find evidence that 'any of those surveillance planning activities had been completed for Whyalla Airlines during the development of the 1999-2000 surveillance program' (Exhibit C97, p97).

4.11. The surveillance planned for Whyalla Airlines for the 13 months prior to 31 May 2000, when compared with the actual surveillance which occurred during that period is depicted in a table on page 98 of the ATSB report. As the executive summary of the report notes:

> 'In common with the published findings of other reports on CASA surveillance activities, there was a significant under-achievement of surveillance of the company against CASA's planned levels during that period.' (Exhibit C97, page x)

4.12. As to why this shortfall occurred, the report notes:

> 'The formulae for programming ASSP detailed in the manual took no account of staffing levels which would have been required to complete the program or which were available in the various offices. Indeed, in many cases Area Offices would not have been able to complete their surveillance programs, prepared in this way, even if they were fully staffed. In 1999 and 2000, however, the Adelaide Office had fewer than 50% of its complement of flying operations staff and so the program of surveillance set down for flying operations in general, and for the Whyalla Airlines AOC in particular, was never capable of completion. As a result, in order to manage the process as effectively as possible, tasks that were scheduled for Whyalla Airlines for a particular month were commonly done in conjunction with other tasks at a different time.
>
> Problems in achieving surveillance targets at the time of the accident were not restricted to Whyalla Airlines or to the Adelaide district office. Deficiencies in CASA's surveillance planning and achievement during the same period are already documented in two audit reports compiled in 1999; one by the Australian National Audit Office and the other by the International Civil Aviation Organisation.' (Exhibit C97, p98)

4.13. Since 1998, CASA had been developing a different approach to surveillance of aviation safety which was in the process of being introduced when this accident occurred. The new process included the development of a safety trend indicator (STI) questionnaire in order to systematically assess the functioning of all certificate holders throughout the country to enable surveillance resources to be more efficiently targeted. It does not appear that an STI was developed in relation to Whyalla Airlines prior to the accident. The ATSB report notes:

> 'The surveillance planned for a low capacity RPT operator like Whyalla Airlines under CASA's new program is now a three yearly re-certification audit (in line with the 3-year AOC cycle) and an annual visit. Other (risk-based) audits may be conducted as a result of an identified risk. The new program also focuses on system/organisation based auditing rather than product/task based audits (as in the past).' (Exhibit C97, p100)

(Signed)

4.14. <u>Whyalla Airlines 'Safety Culture'</u>

Consistent with the issues raised by CASA in June 2000 which led to the suspension of Whyalla Airlines' AOC, a number of issues were canvassed at the inquest which were concerned with the suggestion that there were work practices and organisational factors that were inconsistent with aviation safety and which may have been relevant to the events of 31 May 2000.

4.15. <u>Turnaround Times</u>

There was some evidence that the Whyalla Airlines schedule was very tight, and allowed insufficient time during 'turnarounds' for the pilot to perform his duties including checking the fuel and other routine safety matters. During turnarounds, pilots were expected to load and unload passengers' baggage, check-in passengers, transfer passengers to other airlines (including on occasions driving them to different sections of the airport), handle ticketing problems, attend to refuelling, clean and tidy the aircraft, and attend to the necessary formalities for the ensuing flight. (See the evidence of Mr Kuch C170b, Mr Beattie C174, Mr Hill T1837)

4.16. The turnarounds were so busy that Adelaide-based pilots were even expected to come into the airport on days when they were rostered off-duty, and assist the pilot with these duties (see the evidence of Mr Usher C172 and Mr Hill T1837).

4.17. Without analysing this evidence in great detail, it must be acknowledged that the pilots were busy during turnarounds and under pressure from Mr Kym Brougham to achieve the schedule. However, there is no evidence before me that can specifically link the turnaround times to any errors or incidents with the possible exception of an incident on 28 February 2000, when pilot Mr Nick Reymond in VH-NPB departed Adelaide with insufficient fuel, and was required to turn back and refuel (see Exhibit C171). In the many flights which occurred during the relevant period, this seems to have been an isolated incident from which it is difficult to draw more general conclusions.

4.18. The former pilot who was most critical of Whyalla Airlines was Mr Tim Kuch who was the Airline Safety Officer from 8 March 2000 for a short period. Even Mr Kuch was prepared to acknowledge that whilst turnaround times were tight, 'everything always managed to get done' (T1562).

(Signed)

4.19. Mr Chris Brougham pointed out, with considerable justification, that the airline had been operating with the same timetable since its inception ten years earlier, and it had been inspected and audited by CASA on a number of occasions (Exhibit C74b, p12). Mr Kym Brougham made the same comment (Exhibit C73f, p8).

4.20. <u>Departure Time of Flight 904</u>

The schedule published by Whyalla Airlines (Exhibit C171b) discloses that Flight 904 was due to depart Adelaide at 6:15pm and arrive in Whyalla at 7:10pm. Clearance was given by Adelaide Flight Control to taxi at 1820:14 (Exhibit C98a), and at 1821:46, MZK was cleared for takeoff.

4.21. Counsel for AirServices Australia, Mr McKeown, submitted that MZK was behind schedule when it took off on its last flight.

4.22. Mr Kym Brougham argued that MZK actually departed Adelaide on time. He said that 6:15pm was in the schedule as an indication of the boarding time for passengers and not the takeoff time of the aircraft (T2542).

4.23. The transcript of the radio transmissions from MZK demonstrates that when Mr Mackiewicz radioed Adelaide Flight Information Service at 1856:03, and advised that he was estimating Whyalla at 1908, he was expecting to arrive a little earlier than scheduled.

4.24. Having regard to the totality of the evidence on this issue, I am not prepared to find that the safety of Whyalla Airlines was compromised by the schedule it operated. There is no evidence that Mr Mackiewicz had any more difficulty than the other pilots did in complying with it, or that he felt any particular stress arising from it, to the extent that this may have affected his performance on 31 May 2000. In any event, the evidence establishes that Flight 904 departed Adelaide on time, and there is no evidence of any difficulty or haste during the turnaround.

(Signed)

4.25. Pilot's duty times

The ATSB final report, Exhibit C97 states:

> 'To minimise the likelihood of fatigue influencing crew performance CASA prescribes limits on the flight and duty times for pilots. CAO 48 provided the following requirements:
>
> 1.13 - An operator shall not roster a pilot to fly when completion of the flight will result in the pilot exceeding 90 hours of duty of any nature associated with his employment in each fortnight standing alone. For the purposes of this paragraph, duties associated with a pilot's employment include reserve time at the airport, tours of duty, dead head transportation, administrative duties and all forms of ground training. The operator shall designate the day on which the first of the fortnightly periods shall start.
>
> The Manager of Whyalla Airlines indicated that dead head transportation had not always been included in the calculations of pilots' flight and duty times. Also, the periods that pilots assisted with tasks such as baggage and ticketing during aircraft turn-arounds was also not recorded as flight and duty time. In its audit of the company after the accident (see 1.19.2) CASA found inaccuracies in flight and duty records.'
>
> (Exhibit C97, p108)

4.26. Ms Samantha Koehne, who had been living with Mr Mackiewicz for five months prior to the accident, made some non-specific allegations that these obligations were not being met. She said:

> 'During this period of time there were often days where Ben would be flying when he was not meant to. As I understand it he was only meant to fly for 6 days straight and then was required to have 36 hours off. There was about 4 or 5 occasions when Ben would return after a flight and would say something to the effect of "Kym's rigged the books again, I wasn't meant to be flying today." I understood this to mean that he had flown for more than six days straight and in any case I knew he had flown for more than six days straight as I was living with him.' (Exhibit C38c, p1)

Later in her statement, Ms Koehne says:

> 'There was about 4 or 5 times when Ben would return home and say, "Just call me 'Tim' or he would use some other pilots name. That was because he had been flying when he was not meant to.
>
> At least once a month he would get a phone call from Kym Brougham or Dave Usher to assist at the air-port in Adelaide with a turn around. That is to help with booking in of passengers and loading baggage. This would be on one of his rest days.
>
> As far as I know Ben was recording all of his hours on his log book. About 3 months ago Ben started to maintain a personal dairy of all of his flying hours and destinations. There were occasions where I saw him physically make entries into the diary.'
>
> (Exhibit C38c, p3)

4.27. One specific incident referred to by Ms Koehne is as follows:

> 'I do recall one particular incident in about August 1999. I was still living in Whyalla at the time and Ben was supposed to be staying with me this particular night. Ben had flown during the day and he arrived at my place between 5 pm and 6 pm. Around 9 pm this night, Kym Brougham rang Kym (Ben) on his mobile telephone and asked Ben to conduct a charter flight.
>
> Ben was angry at Kym for having to do this flight and protested about his duty hours. I heard the conversation but am unable to recall specifically what was said but I formed the impression from this conversation that Ben had already completed his duty for the day and by completing this charter, Ben would be in breach of his duty times.
>
> Following the telephone call from Kym, Ben told me the charter was to fly one person to Melbourne from Whyalla that night and that the charter was scheduled to leave Whyalla at 11 pm using the Cessna 210 aircraft.
>
> Ben left the house around 10.30 pm to prepare the aircraft. I spoke to Ben the following day and he told me he had flown a male passenger to Melbourne and returned to Adelaide airport. He told me he did not get back until between 4 am and 5 am that morning. I am unsure if the passenger returned on the flight. I do not know if Ben worked at all that same day following his return from Melbourne.'
>
> (Exhibit C38d, paragraph 12-15)

4.28. The ATSB conducted an analysis of Mr Mackiewicz's flight and duty times for the five days prior to 31 May 2000. A summary of this information is as follows:

- Saturday 27 May 2000 - rostered off
- Sunday 28 May 2000 - on duty at 1630, flew Adelaide to Cleve and Wudinna at 1700, and then returned to Adelaide at 1900. Travelled from Adelaide to Whyalla as a passenger arriving at 2130.
- Monday 29 May 2000 - commenced duty at 0700. Flew Whyalla to Adelaide service at 0730, returned to Whyalla arriving at 0945. Studied for an aviation theory examination during the day. Then travelled to Adelaide as a passenger on the 1700 flight, recorded off duty at 1800.
- Tuesday 30 May 2000 - on duty at 0630 hours. Flew Adelaide to Cleve and Wudinna service at 0730, then the 0850 return flight to Adelaide, arriving at 1010. Off duty at 1030.
- Wednesday 31 May 2000 - on duty 1430 hours. Flew charter flight from Adelaide to Port Pirie departing 1500. Continued Port Pirie to Whyalla arriving 1630. Flew the Whyalla to Adelaide service at 1700 hours and was on the return journey when the accident occurred.

4.29. From these records it can be seen that Mr Mackiewicz's duty times were not excessive during those five days. In particular, on 31 May 2000 he had been on duty since 2:30pm that afternoon, and he had not worked since 10:30am the previous day.

(Signed)

4.30. On that basis, I agree with the author of Exhibit C97 when he comments:

> 'The information available does not indicate that the pilot was affected by fatigue at the time of the accident.' (Exhibit C97, p7)

4.31. An analysis of the records in relation to the other pilots at Whyalla Airlines was conducted by CASA after 31 May 2000. Analysis of pilot's time sheets and information obtained from AirServices Australia reveals a number of discrepancies which are of much greater extent than those in relation to Mr Mackiewicz (see the statement of Mr Docking Exhibit C84a).

4.32. There were also allegations that when pilots were required to stay overnight in Whyalla, the accommodation provided to them was substandard to the extent that pilots were expected to sleep in circumstances where socialising at the premises would often interfere with their ability to do so (see the evidence of Mr Usher C172, Mr Hill C173, Mr Beattie C174 and Ms Koehne C38c).

4.33. This matter also caused CASA some concern, but for the reasons I have outlined above in relation to the five days prior to 31 May 2000, I do not consider it relevant for present purposes.

4.34. <u>Car ferrying</u>

Another complaint against Whyalla Airlines was that pilots were required to ferry Hertz rental cars, usually between Whyalla and Adelaide, during times that were not recorded as part of their duty time. Mr Usher alleged that this would occur on average once a week (Exhibit C172a, p2).

4.35. An analysis of the proven facts suggests that this is something of an exaggeration. Mr Chris Brougham said that over a period of twelve months the Hertz company identified only eight occasions when this had occurred (Exhibit C74b, p10). (Mr Brougham's letter to CASA of 5 July 2000 says there were 15 occasions).

4.36. Most importantly, there is only one occasion where it is recorded that Mr Mackiewicz was required to ferry a Hertz car and that was on 9 June 1999. This is clearly irrelevant for present purposes.

4.37. Kym Brougham's management style

The evidence is clear that Mr Kym Brougham had a rather abrupt and perhaps insensitive way of dealing with his employees. His brother Mr Chris Brougham, in closing submissions, described his brother's approach as 'hard but fair' (page 3).

4.38. For example, Mr Peter Docking, a Flying Operations Inspector employed by CASA, outlined an occasion when he witnessed Mr Brougham chastising a pilot for his late arrival at Whyalla Airport. Mr Docking described Mr Brougham's attitude as 'stern and abrupt' (Exhibit C84a, p4).

4.39. The evidence of Mr Kuch (T1405 and T1407), Mr Usher (Exhibit C172, p5) and Mr Hill (T1838) was to similar effect.

4.40. This attitude of Mr Brougham must be seen in the context that the pilots employed at Whyalla Airlines had very little security of employment. None of them were employed pursuant to a written contract (Mr Reymond C171, p2; Mr Usher C172, p3 and Mr Hill C173b, p2), and this was particularly the case after the 11 June 1999 incident when Mr Brougham suspended Mr Mackiewicz from RPT flying for a period of three months or more. Ms Koehne described occasions when Mr Mackiewicz would ask Mr Brougham if he was still employed after that incident, and Mr Brougham would reply 'we'll see' (Exhibit C38d, p3).

4.41. Another aspect of Mr Brougham's management style was the way he devised nicknames for his pilots. For example, Mr Mackiewicz's nickname was 'Slow' and Mr Hill's and Mr Kuch's nickname was 'Slack' (see Exhibit C38d, p5 and T1856).

4.42. Mr Brougham replied that these nicknames were used in jest, and confessed that his own nickname was 'Grumbler' (T2553).

4.43. Several witnesses indicated that it was their impression that Mr Brougham treated Mr Mackiewicz more harshly than he did the other pilots (see evidence of Mr Kuch T1408, T1488 and Mr Hill T1857).

4.44. It is difficult to know what to make of this evidence. Clearly, Mr Brougham was something of a disciplinarian and a perfectionist, and it may well be that he did not appreciate the extent to which the pilots found his behaviour threatening. It may be that he failed to recognise the imbalance of power in the employer-employee relationship and the extent to which, in that context, a pilot may have taken his comments to heart. These were young men who were in the early stages of building a career, and any setback such as being dismissed from employment would be a serious matter for them. It is no surprise that they were highly anxious about the security of their employment.

4.45. Having said that, I have received evidence from various people that they were convinced that nothing arising from the relationship between Mr Mackiewicz and Mr Brougham would have influenced the way that Mr Mackiewicz flew MZK on the night of 31 May 2000. I will go into this issue in more detail later in this finding.

4.46. However, this is a serious issue, and one that deserves close attention by CASA. It is no secret that young pilots are very keen, if not desperate, to progress in the industry, and in those circumstances they are highly susceptible to pressure, whether intended or otherwise, from their employer to maintain schedules and a high degree of performance. The temptation in those circumstances may well be to cut corners and compromise flight safety and that is a serious matter indeed.

4.47. Maintenance Releases and Incident Reporting

A ‘maintenance release’ is a document prepared by a pilot once each day describing the performance of the aircraft, keeping a record of various statistics concerning its performance, and recording any defects or incidents which became apparent to the pilot during the course of the day’s flying. A collection of these documents, which span a nine-month period, is Exhibit C151.

4.48. Mr Kuch gave evidence that he was the Safety Officer for the airline for a short period in 2000. He was concerned about the fact that instead of receiving incident reports from the pilots, they were required to be submitted to Mr Kym Brougham and Mr Brougham would take it upon himself to decide whether the Safety Officer should be informed or not (T1411 and T1418). Mr Kuch also alleged that on at least one occasion, a pilot’s initials were put on a maintenance release by a person other than that pilot (T1449).

4.49. Mr Kuch explained that pilots were under instructions not to record a defect on an aircraft until the aircraft was in a location where it could be repaired (T1533). This allegation was supported by Mr Hill (T1893), although it was denied by Mr Brougham (T2655) and Mr Reymond had no memory of such a practice (T1623).

(Signed)

4.50. One incident which particularly concerned Mr Kuch occurred on 30 May 2000, the day before the accident. Mr Kuch was scheduled to take a charter flight to Cook from Whyalla in the Beechcraft Baron VH-ION**.** As a coincidence, Mr Kuch had dinner during the evening of 29 May 2000 with Mr Ben Auld, who had been using the aircraft for training that day and who told Mr Kuch that the vacuum pump was either unserviceable, or 'on the way out' (T1450). Mr Kuch recalled that earlier that day he had spoken to Mr Brougham about the aircraft but Mr Brougham had said nothing about any such problem. He spoke to Mr Brougham again on 30 May 2000 and Mr Brougham told him there was nothing at all wrong with the vacuum pump.

4.51. During the charter flight the following day, the vacuum pump failed during the flight from Cook to Port Lincoln where the aircraft was being taken for repairs to a seat.

4.52. This incident illustrates that there was a somewhat 'gung-ho' attitude on Mr Brougham's part, and it is corroboration for the suggestion that there was some slackness in the incident reporting procedures maintained at Whyalla Airlines.

4.53. While a matter of concern, however, this incident does not relate directly to the incidents of 31 May 2000. As it happened, MZK had completed an extensive 100 hourly inspection the day before the flight, and there was no evidence that any other defects had been identified in the aircraft prior to Flight 904. In those circumstances, it cannot be concluded that any failings in Whyalla Airlines incident reporting system was causally relevant to the tragedy which ensued.

4.54. Issues, Discussion and Conclusions

4.55. *Were there any work practices or organisational factors at Whyalla Airlines which may have caused or contributed to the events of 31 May 2000?*

4.56. The issue of whether a 'safety culture' existed at Whyalla Airlines was initially raised by CASA after 31 May 2000. On the evidence before me, I find that the management of Whyalla Airlines, and Mr Kym Brougham in particular, demanded efficiency and hard work from their employees, and that Mr Brougham was a hard taskmaster in many respects. There is no evidence before me that specifically establishes a connection between any work practices or organisational factors at Whyalla Airlines and the events of 31 May 2000.

4.57. *Was the turnaround time between Flight 903 and Flight 904 sufficient so that Mr Mackiewicz could prepare and plan his flight with safety?*

4.58. There is no evidence that there was any difficulty in the turnaround before Flight 904 on 31 May 2000.

4.59. *Was Mr Mackiewicz required to work beyond his statutory duty times so that fatigue may have been a factor in the events of 31 May 2000?*

4.60. The evidence suggests that Mr Mackiewicz's duty times were not excessive during the five days prior to 31 May 2000, and so there is no evidence that Mr Mackiewicz might have been unduly fatigued during Flight 904.

4.61. *Was Mr Mackiewicz required to ferry hire cars so that fatigue may have been a factor in the events of 31 May 2000?*

4.62. The evidence discloses that Mr Mackiewicz was required to ferry a hire car on only one occasion, almost a year before 31 May 2000. There is no evidence that this is in any way relevant to what happened on 31 May 2000.

4.63. *Was Mr Kym Brougham's management style such that it may have compromised safety which could have caused or contributed to the events of 31 May 2000?*

4.64. Although Mr Kym Brougham's management style could be described as disciplinarian and perfectionist, and his tendency to use the threat of dismissal as a way to manage his staff may have placed undue pressure upon them, the evidence before me is that this would not have acted upon Mr Mackiewicz in such a way that it may have caused or contributed to the events of 31 May 2000.

4.65. *Was the practice of reporting defects/incidents at Whyalla Airlines such that safety was compromised at Whyalla Airlines?*

4.66. Although there is some suggestion of a 'gung-ho attitude' on Mr Brougham's part, the fact that MZK had an extensive 100 hourly Check 2 and 3 inspection which culminated on 30 May 2000 rendered any such concerns irrelevant to the events of 31 May 2000.

(Signed)

5. VH-MZK

5.1. VH-MZK (MZK) was a Piper PA31-350 Chieftain aircraft built by the Piper Aircraft Corporation in 1981 in the United States of America. At the time of the accident, its airframe had been in service for an estimated 11,837.6 hours (Exhibit C97, p8).

5.2. MZK was imported to Australia and a Certificate of Airworthiness (No. BK 1561) was issued by CASA on 2 June 1988.

5.3. Whyalla Airlines Pty Ltd purchased MZK in 1995. A Certificate of Registration (No: BKN/01561/03) was issued by CASA on 27 March 1995.

5.4. The left engine in MZK was manufactured by Textron Lycoming in the United States of America in 1977. It was originally configured as a TIO-540-A2C model engine, it was overhauled and converted to a TIO-540-J2BD in May 1997, and was then overhauled and converted to a TIO-540-J2B in January 2000. It was fitted to MZK in February 2000, after undergoing a 'factory overhaul'. This was necessary because the previous left engine was damaged, leading to a forced landing at Maitland, South Australia, on 7 January 2000.

5.5. The right engine in MZK was manufactured by Textron Lycoming in 1980 as a LTIO-540-J2BD model. It was reconfigured as a TIO-540-J2B model in 1998 and was installed, after a factory overhaul, in November 1998.

5.6. Maintenance History

The ATSB report conveniently sets out a brief summary of MZK's service history since December 1998 when the right engine was installed. A reference to a Check 2 means a mechanical service which was to be completed after each 100 hours (maximum) time in service, or 12 months (whichever was the earlier). Items included in Check 2 are:

> Propeller - Spinner, blades, lubricate, propeller air pressure (monthly), feathering of the propeller.
>
> Engine - General inspection, oil strainer, oil filter change and inspection, replace oil, spark plugs clean and adjust, cylinder compression, ignition harness and insulators for high tension leakage and continuity, magnetos points and timing, clean air screen, clean fuel injectors, tension alternator belt, compressor oil level and tension of belt.

Turbocharger - Turbine wheel inspection in accordance with Lycoming SB 452, induction and exhaust components (Piper SB 644), alternate air door operation, operation of compressor bypass door. (Exhibit C97, p127)

A reference to a Check 2A means a service which was due to be completed 50 (+/-5) hours time in service after the Check 2 and 3 were completed. Items included in the Check 2A are:

Engine group - Cowls inspection, replace engine oil and oil filter, inspect oil filter element, AD/PA31/96 engine baffles inspection. (Exhibit C97, p127)

A reference to a Check 3 means an airframe service, which was also to be completed every 100 hours (maximum) time in service or 12 months (whichever was the earlier). Items included in Check 3 are:

Airframe - Cabin, fuselage and empennage, wing, landing gear, electrical and instrument groups. (Exhibit C97, p127)

5.7. The service history of MZK is as follows:

'4 December 1998 (10,442.4 hours) - Check 2 and 3 carried out. Right engine replaced. Right engine baffles replaced. Right engine mount frame overhauled.

29 December 1998 (10,493.8 hours) - Check 2A carried out.

4 January 1999 (10,520.1 hours) - Right engine #5 and #6 fuel injectors cleaned.

15 January 1999 (10,542.4 hours) - Check 2 and 3 carried out.

29 January 1999 (10,594.2 hours) - Check 2A carried out.

12 February 1999 (10,641.3 hours) - Check 2 and 3 carried out.

19 February 1999 (10,673.0 hours) - Overhauled propeller installed on the right engine.

23 February 1999 (10,689.5 hours) - Check 2A carried out.

10 March 1999 (10,741.3 hours) - Check 2 and 3 carried out. Two spark plugs on left engine replaced.

8 April 1999 (10,840.1 hours) - Check 2 and 3 carried out. One spark plug left engine replaced.

6 May 1999 (10,939.6 hours) - Check 2 and 3 carried out. Left engine #4 exhaust stack replaced.

21 May 1999 (10,990.1 hours) - Check 2A carried out. Overhauled propeller fitted to the left engine.

9 June 1999 (11,037.8 hours) - Check 2 and 3 carried out. Three spark plugs on left engine replaced.

28 June 1999 - Check 2A carried out.

16 July 1999 (11,136.6 hours) - Check 2 and 3 carried out. Six spark plugs right engine replaced.

2 August 1999 (11,182.1 hours) - Check 2A carried out.

20 August 1999 (11,234.6 hours) - Check 2 and 3 carried out.

9 September 1999 (11,289.4 hours) - Check 2A carried out.

30 September 1999 (11,334.0 hours) - Check 2 and 3 carried out. Right engine magnetos timing adjusted. Two spark plugs on right engine replaced.

14 October 1999 (11,377.5 hours) - Check 2A carried out. New turbocharger fitted to left engine.

2 November 1999 - As a result of CASA surveillance and the issuing of an Aircraft Survey Report the following work was undertaken. Compass card updated. Right throttle, mixture and pitch controls adjusted. Left mixture and propeller cables adjusted. Hydraulic flexible hose replaced. Lower left cowl fastener replaced. Left alternator drive belt tension adjusted. Corrosion removed on underside of left horizontal stabiliser spar and area painted. Elevator trim upper bushes replaced. Right aileron control rod aft rod end renewed.

12 November 1999 (11,433.5 hours) - Check 2 and 3 carried out.

1 December 1999 (11,487.4 hours) - Check 2A carried out.

17 December 1999 (11,533.5 hours) - Check 2 and 3 carried out. SI5.2 (Special Inspection) - Oil coolers flushed. Right engine right magneto timing adjusted. Right engine baffle seal replaced. Three spark plugs on right engine replaced.

29 December 1999 (11,588.6 hours) - The maintenance release was endorsed with "LE [left engine] slight miss idle, high ffs [fuel flows], low EGT [exhaust gas temperature]? Is an injector blocked".

30 December 1999 - Partially blocked left engine #4 fuel injector nozzle cleaned.

7 January 2000 (11,575.6 hours) - The maintenance release was endorsed with "LE [left engine] u/s [unserviceable] the aircraft is unairworthy".

13 February 2000 (11,575.6 hours) - Left engine replaced with factory overhauled engine. New EGT probe installed on the left engine. Left engine baffle repairs carried out as necessary. Left engine mounts replaced. Left engine mount frame paint stripped, weld repair, leg straightened and tested. Left engine hoses re-manufactured. Left engine overhauled propeller governor installed. SI5.1 (Special Instruction) - Right engine crankshaft de-sludge.

21 February 2000 (11,583.5 hours) - Check 2A carried out on right engine.

4 March 2000 (11,630.6 hours) – The maintenance released was endorsed with "LE [left engine] sometimes runs on when shutting down", "RH [right hand] fire shutoff stiff to operate" and "LE [left engine] oil T [temperature] hi [high], sometimes unsteady?" Each defect was cleared by being categorised as non-major, and entered on the deferred defects list.

9 March 2000 (11,632.2 hours) - Check 2 and 3 carried out. Left oil temperature wire crimp replaced. Right firewall shutoff seals replaced. Four spark plugs on right engine replaced.

30 March 2000 (11,682.1 hours) - Check 2A carried out. Left propeller governor leaking. Replaced with overhauled governor.

22 April 2000 (11,730.7 hours) - Check 2 and 3 carried out. Fuel calibration carried out.

8 May 2000 (11,784.5 hours) - Check 2A carried out.

9 May 2000 (11,789.2 hours) - The maintenance release was endorsed with "left eng [engine], left mag [magneto] not working properly". No clearing certification was made. Maintenance worksheets recorded the problem as "LH [left] magneto on LH [left] engine missing" and maintenance action included removal of the magneto, a 500 hourly inspection, spark plugs tested, refitting of the magneto and ground runs. No defect was identified.

10 May 2000 (11,791.6 hours) - The right magneto on the left engine was bench tested. The defect was recorded as "missing at altitude". The worksheet was endorsed with '500 hourly inspection completed on magneto. No defects found apart from contacts open excessively and consequently "E" gap out. Contacts and timing reset. Magneto bench tested satisfactory'.

15 May 2000 (11,811.8 hours) - Right engine starter motor replaced.

30 May 2000 (11,830.2 hours) - Check 2 and 3 carried out.' (Exhibit C97, p 9-12)

5.8. Mr Karl Jelinek, the Chief Engineer and Managing Director of Tuna City Aviation, told me that during a factory overhaul of an engine, the crankshaft would not necessarily be replaced. It would be examined for cracking and its dimensions would be checked. If necessary, it might be re-machined, re-nitrided (hardened) and fitted with appropriately sized bearings (T779).

5.9. <u>Oil filters</u>

Mr Jelinek told me that if, as has been postulated by the ATSB in its report (Exhibit C97), the No.6 main bearing of the left crankshaft had been in the process of decomposition over at least the last 50 flights (which according to the Trend Monitoring Data, Exhibit C151, was between approximately 28 April and 5 May 2000), then he and his engineers would have found signs of this in the form of metal particles in the oil filters (T802).

5.10. For example, in February 2002, disintegrating bearings were diagnosed by this method in another aircraft. Mr Stefan Jelinek, brother of Karl, is the Chief Pilot for Oil Drilling and Exploration Ltd. He told me:

> 'The company experienced an engine problem on VH-OMM in February 2002. On a routine 100 hourly inspection, 2 small particles of white metal were found in the suction filter. There was no metal or contamination found in the pressure filter. The aircraft was flown on one more flight and the suction filter rechecked where 4 small pieces of metal were found. As a result the engine was bulk stripped by Approved Aircraft Maintenance, Toowoomba. Several main bearings were found in various stages of de-lamination or breaking up. From the information provided to me and from my experience I consider that the engine would have failed within ½ to 2 hours of flight time.' (Exhibit C175, page 4)

5.11. A Check 2A was carried out on 8 May 2000, and the oil filters were checked, with no result. On 30 May 2000 during the Checks 2 and 3 the engineer, Mr Paul Jones, said he found no such particles in the left engine oil filters (T908). Mr Rodney Parker, the engineer who worked on the right engine, said he found no abnormalities in those oil filters either (T939).

5.12. Mr Possingham, counsel for Textron Lycoming, cross-examined Mr Karl Jelinek about the fact that a total of four oil filters (Part No. CH48110) appeared in the invoices arising from the Check 2 and 3 inspections which culminated on 30 May 2000, instead of the usual two. Mr Jelinek denied that the first filter may have been contaminated, was replaced, and then cleared after the 'ground run' (T875). He was unable to explain why four filters were needed, and speculated that his secretary may have simply 'tacked on' charges for two filters which may not have been charged for in a previous service (T876).

5.13. Mr Jelinek pointed out that during a previous inspection on 22 April 2000, when three oil filters were charged for, an inspector from the Civil Aviation Safety Authority was present at his workshop throughout, and followed the servicing closely (T876).

5.14. Mr Jelinek pointed out that inspection of the oil filters is an important function. He said:

> 'I think it's a fairly critical job and I mean everyone is aware of the repercussions of finding contaminants in the oil filter, I mean that is one of the first jobs we always do once you have drained the engine to see whether you continue on with the servicing of the engine, so it's a fairly important job.' (T877)

(Signed)

5.15. Mr Kym Brougham told me that from his experience, he would have expected Mr Jelinek to contact him immediately if an oil filter had been contaminated and he received no such contact (T2856).

5.16. Dr Arjen Romeyn, ATSB's Chief Metallurgist, explained that since there were no particles found during those service inspections, either the particles given off as a result of the failing bearings were too small to be caught by the filters and were suspended in the oil, or the damage occurred after the last inspection on 30 May 2000, or at least the particles were only released after that last inspection (T4313). For reasons I will discuss later, this explanation seems unlikely to be correct.

5.17. Dr Romeyn agreed that the only way such fine particles could be detected is by spectrographic oil analysis (T4311).

5.18. I heard evidence in America from Mr George Braly, to whom I will refer to in much greater detail later, that he routinely has oil tested in this way in relation to his aircraft (T3300). He said that it is inexpensive and can provide an early warning of not only bearing damage, but also the type of damage which was apparent on the right engine of MZK after it failed (T3302). Spectrographic analysis was not performed at any of the MZK service inspections, nor did Textron Lycoming, the engine manufacturer, require it to be.

5.19. <u>Spark Plugs</u>

The suggestion arose during the hearing that the failure of a spark plug may have led to detonation, which may have caused abnormal cylinder temperatures and pressures, which may have contributed to the failure of the left crankshaft, and to the holing of the No.6 piston in the right engine.

5.20. Mr Possingham explored the possibility that, during the Checks 2 and 3 culminating on 30 May 2000, a spark plug may have been dropped and damaged, or was otherwise defective. Both Mr Jones and Mr Parker, the engineers who worked on the left and right engines respectively, denied that this occurred. Mr Jones said that he checked and cleaned the spark plugs in the left engine (T928) and Mr Parker did the same on the right (T940).

5.21. Dr Manfred Zockel, Visiting Research Fellow in Mechanical Engineering at Adelaide University, told me that there are two spark plugs in each of the six cylinders in each Textron Lycoming engine. He said that if one spark plug is lost, it is easier for end gas detonation to occur (T2090).

5.22. As was noted by the ATSB, one of the spark plugs in the No.6 cylinder in the right engine had a significant deposit of aluminium, which would have shorted that spark plug out, preventing it from operating. Dr Zockel explained:

> 'A. Yes, what I'm postulating is that if some form of pre-ignition had occurred, that's pre-ignition, some external source, had occurred during an earlier phase of the flight, could have been during take-off or climb or whatever, the possibility of a particle of aluminium from the top of the piston could have gone on to that spark plug and shorted so that even when you reduce the boost from the engine, reduce the power consumption from the engine, where detonation should not have occurred under any circumstances, it is still possible to get detonation, end-gas detonation.
>
> Q. Because you've got one spark -
>
> A. One spark plug out.
>
> Q. Out.
>
> A. Yes. It's easier for that end-gas to detonate with one spark plug because the flame front has to travel much further.' (T2091)

5.23. Dr Zockel tested the twelve spark plugs from the right engine of MZK in December 2002. The No.1 spark plug was coated with aluminium from the No.6 piston and had shorted out. It had been dismounted and the ceramic insulator was broken, but after it was cleaned and 'refurbished', a regular spark was obtained. Several of the plugs malfunctioned as a result of an excessive gap between the electrodes, indeed Dr Zockel observed that 'all but two plugs have gaps more than 20% greater than the specified value' (Exhibit C233, page 3).

5.24. Dr Zockel's conclusions, expressed as 'tentative', were as follows:

> 'The following tentative conclusions may be drawn:
>
> 1 The cylinder with number 3 and 4 spark plugs may have experienced some intermittent operation since both spark plugs failed to provide regular sparks at 125psi.
>
> 2 No 6 cylinder with no1 and 2 spark plugs may also have had weak or intermittent sparks. The problem would have been exacerbated after No 1 spark plug was shorted by the metallic deposits.

3 All other cylinders had at least one spark plug which fired regularly under the test pressure. In the operating engine the pressures are somewhat higher than the test pressures but so are the temperatures which makes it easier for the spark to discharge. Consequently the test pressure is a reasonable representation of the in cylinder conditions.

Overall I do not consider the spark plugs on the right hand engine to have contributed significantly to the crash.' (Exhibit C233, page 4)

I accept Dr Zockel's findings, and conclude that there is no evidence that damaged or defective spark plugs contributed to the failure of either engine.

5.25. Magnetos

As I have already outlined, a factory-overhauled engine was installed in MZK on the left wing in February 2000 following the engine failure which led to a forced landing at Maitland, South Australia, on 7 January 2000. Mr Jelinek told me that the engine would have had new magnetos fitted. (A magneto is a device which determines the precise time at which electric current is delivered to the spark plug of the engine, thereby igniting the fuel/air mixture in the cylinder. It is therefore said to regulate the 'timing' of the engine.) As the settings may be disturbed during installation, the magnetos would be checked after installation, and at every 100 hour (Check 2) inspection thereafter (T788).

5.26. During the Check 2 inspection culminating on 30 May 2000, the operation of the magnetos would have been checked, as such a check is on the schedule (Exhibit C150). The schedule states:

> 'Check magnetos to engine timing (20 degrees BDC [before dead centre])'
>
> (Exhibit C150)

Mr Jelinek said that in the absence of a notation that extra work was performed, he was able to state that no adjustment of the engine timing was necessary (T798-99).

5.27. Mr George Braly, the engineer from whom I took evidence at his test facility at Ada, Oklahoma in the United States of America, told me that in his opinion the engine timing of the left engine of MZK was seriously wrong after the aircraft returned to service on 13 February 2000, until 9 March 2000 when it was next serviced. He drew this conclusion from the figures in the Trend Monitoring Data (Exhibit C151), which he said indicated that the cylinder head temperatures (CHT) were high, but the exhaust gas temperatures (EGT) were low. He suggested that these symptoms were consistent with detonation having occurred, which may have initiated, or accelerated the failure of the left crankshaft (T3299).

5.28. With the highly sophisticated equipment available at Mr Braly's facility, he was able to alter the timing of an engine and demonstrate the effects of doing so. As I have already said, the maintenance specification is that the spark should occur when the timing wheel is at 20 degrees BDC.

5.29. By advancing the spark to occur at 25 degrees BDC, the EGT dropped, but the CHT rose as did the peak internal cylinder pressure (T3203).

5.30. An examination of the Trend Monitoring Data (Exhibit C151) for the left engine in the relevant period is as follows:

Date	Left EGT	Right EGT	Left CHT	Right CHT
13/2/00	1350	1550	340	370
20/2/00	1550	1550	410	350
21/2/00	1575	1575	420	380
22/2/00	1500	1575	460	410
23/2/00	1550	1600	420	360
24/2/00	1500	1600	440	380
25/2/00	1500	1600	440	380
26/2/00	1500	1550	440	380
27/2/00	1525	1550	445	380
28/2/00	1500	1600	410	390
29/2/00	1500	1590	440	380
1/3/00	1500	1600	450	400
2/3/00	1500	1600	460	400
3/3/00	1550	1600	450	350
4/3/00	1530	1575	440	375
9/3/00	1550	1550	420	360

(Exhibit C151)

5.31. It can be seen from the above data that the highest CHT for the left engine was 460° on 22 February 2000, while the right engine recorded 410°. Mr Jelinek said that although the figures for the left engine were 'getting high', he pointed out that it was not unusual for new engines to run hotter for a time until they settle down (T807).

(Signed)

5.32. In my opinion, although Mr Braly's observations are supported by the Trend Monitoring Data to some extent, the changes are not so obvious that a definite conclusion can be reached that the timing on the left engine was so badly awry that it contributed to the failure on 31 May 2000.

5.33. On 9 May 2000, the Trend Monitoring Data sheet (Exhibit C151) was endorsed by Mr Mackiewicz as follows:

> 'Left eng, left mag not working properly' (Exhibit C151)

At that time the left EGT was noted as 1550°F, the right EGT at 1550°F, the left CHT at 410°F and the right CHT at 400°F. The maintenance work sheets (part of Exhibit C73j) indicate that the left magneto was removed, a 500 hourly inspection was carried out, the magneto was then reset and tested. The right magneto on the left engine received the same treatment (Exhibit C73j). There is nothing in the Trend Monitoring Data either before or after this work which would indicate that anything untoward was happening in the left engine at that time which could be attributed to faulty or incorrectly adjusted magnetos.

5.34. <u>Issues, Discussion and Conclusions</u>

5.35. *Were there any aspects of the maintenance of MZK which may have caused or contributed to the events of 31 May 2000?*

5.36. The evidence elicited by the ATSB, in particular the service history of MZK, indicates that the aircraft was serviced appropriately, and at appropriate intervals since at least 1998. There is no evidence before me of any shortcomings in either the frequency or quality of the work carried out.

5.37. *Were the left engine oil filters on MZK checked adequately on 8 May 2000 and 30 May 2000 for the presence of metal fragments which would have warned of incipient bearing failure?*

5.38. The evidence of Mr Jelinek and his employees satisfies me that the oil filters in both engines in MZK were checked on both 8 and 30 May 2000 and that no metal fragments were found which would have indicated incipient bearing failure. Mr Jelinek and his staff were aware of the significance of such a finding had it been made.

(Signed)

5.39. *If the bearings were in the process of failure, would such failure have been detected by spectrographic oil analysis? Would such analysis have been carried out?*

5.40. It is not possible to conclude that spectrographic oil analysis would inevitably have detected incipient bearing failure, although there is a high likelihood that it would have done so had the bearings of MZK been progressively failing over 50 to 70 flights, as the ATSB has suggested. As such, it is a process to be recommended.

5.41. *Did anything occur during the service on 30 May 2000 which damaged or rendered less efficient any of the spark plugs?*

5.42. There is no evidence before me that anything happened on 30 May 2000 which damaged or rendered less efficient any of the spark plugs in either engines of MZK.

5.43. *Were the magnetos in both engines appropriately checked and adjusted on 30 May 2000?*

5.44. When the left engine of MZK was replaced in February 2000, it had new magnetos fitted. The settings would have been checked after installation, and after every 100 hour inspection thereafter. Such an inspection occurred on 30 May 2000 and no adjustment was necessary. I accept the evidence of Mr Jelinek that these checks were appropriate.

6. Ben Mackiewicz - pilot

6.1. Ben Mackiewicz was born on 15 June 1978. He grew up in country Victoria.

6.2. Mr Mackiewicz commenced flying training in February 1996 with Mr Malcolm Sharp, the Managing Director and Chief Pilot of Sharp Aviation based in Hamilton, Victoria. He obtained his commercial pilot's licence in November 1996 and a Grade 3 Instructors rating in December 1996. He was employed by Sharp Aviation between June and August 1997 as an instructor, and charter and ferry pilot. He then worked as an instructor in regional New South Wales, and eventually commenced employment with Whyalla Airlines in early January 1999.

6.3. The ATSB final report, Exhibit C97, outlines the Whyalla Airlines induction program contained in their Operations Manual (Exhibit C73h). This included training in procedures following an engine failure during cruise, emergency evacuation, ditching, survival methods on land or water, passenger control during emergencies, night flight, together with practical exercises in single engine flying, single engine approach and landing, feathering and unfeathering of propellers, and other techniques.

6.4. Exhibit C97 records that Mr Mackiewicz completed this program on 21 January 1999.

6.5. The records also outline that Mr Mackiewicz completed a Command Instrument Rating flight test, including single engine handling, on 26 July 1999, and also successfully completed a proficiency check on 5 January 2000.

6.6. At the time of the accident on 31 May 2000, Mr Mackiewicz and Mr Kuch, who joined the company in February 1999, were the two most senior line pilots at Whyalla Airlines. Most of the line pilots at Whyalla Airlines at the time, with the exception of Mr Kym Brougham, were relatively inexperienced and in the early stages of their careers as commercial pilots.

6.7. All of the witnesses who gave evidence at the inquiry, and others who have given statements, have described Mr Mackiewicz as a competent, professional and unflappable pilot. For example, Mr Sharp said that, after his training, Mr Mackiewicz was employed in the company and indeed he was put in charge of the Warrnambool operation of the company. This position required someone of higher ability and higher personal skills to handle that business, and 'we saw fit to put him into that position' (T2384).

6.8. I received extensive evidence about Mr Mackiewicz's competence and professionalism, all of it positive. In particular, I heard comments that he was competent in handling emergencies (Mr Sharp T2430), and generally complimentary descriptions of his airmanship were given (see Mr Kuch T1437, Mr Hill T1853, Mr Beattie T1936, Mr Sharp T2383-4, Mr Thompson T3818, Mr Auld T3605). Several experts commented that having regard to the difficulties he faced, Mr Mackiewicz performed extremely well in relation to the manner in which he controlled the aircraft prior to the ditching (see Mr Heyne T318 and T347, Mr Mellberg T363, Mr Williams T423-424, Mr Burden T527-528 and Dr Brock T1226 and T1245).

6.9. Mr McIlwaine SC, counsel for the ATSB, raised one issue concerning Mr Mackiewicz's training. Mr McIlwaine SC argued that the training records indicated that Mr Mackiewicz had a weakness in his use of the rudder during a simulated engine failure. For example, following a check in January 1999, Mr Brougham noted that Mr Mackiewicz was inclined to 'overcontrolling rudder'. Elsewhere on the document Mr Brougham made the notation:

> 'Excessive overcontrolling of rudder in both correct and incorrect sense, severity increasing as stress builds up while trying to adjust to evertightening steep turn onto final…..' (Exhibit C179a)

6.10. Mr McIlwaine SC seized upon these comments as an important issue in relation to Mr Mackiewicz's handling of MZK during its final journey on 31 May 2000. In particular, he argued that such a weakness may have been important in understanding what happened at 1847:15 when the aircraft diverged 19° to the right. This topic attracted a considerable degree of attention from all parties at the inquest. I will discuss the issue in more detail later.

6.11. Apart from that single issue, all the evidence before me suggests that Mr Mackiewicz was a competent and professional pilot. His training and experience were quite conventional for a pilot working in that industry with that degree of experience, and there is no suggestion that there was any deficiency which was relevant to the events of 31 May 2000. One indicator of his performance under stress was the events of 7 January 2000 (which I will discuss in detail later), and there was nothing in relation to that incident which gave cause for concern.

(Signed)

6.12. Issues, Discussion and Conclusions

6.13. *Was Mr Mackiewicz appropriately trained, qualified and experienced when he piloted MZK on Flight 904 on 31 May 2000?*

6.14. The evidence before me establishes that Mr Mackiewicz was appropriately trained and qualified to act as a pilot in regular passenger transport (RPT) operations according to all criteria set down by the Civil Aviation Safety Authority. He completed Whyalla Airlines' induction program on 21 January 1999, received Command Instrument Rating on 26 July 1999 and underwent a proficiency check on 5 January 2000. Although it was early in his career, Mr Mackiewicz and Mr Tim Kuch were the two most senior line pilots at Whyalla Airlines.

6.15. *Were Mr Mackiewicz's character and personal qualities, as well as his training and experience, such that he was likely to have responded appropriately to an extreme emergency situation such as the one which he confronted on 31 May 2000?*

6.16. The evidence before me establishes that Mr Mackiewicz was a professional pilot who was competent in handling emergencies. Having regard to the particularly adverse conditions on the night of 31 May 2000, expert opinion is unanimous that he handled the emergency well, and that he ditched the aircraft as well as could have been expected in the circumstances.

6.17. *Is the calmness and professionalism evident in Mr Mackiewicz's voice during the radio transmissions after the Mayday call consistent with the allegations of the ATSB that, having regard to his experience in January 2000, the resultant stress caused him to make a serious error in the management of the right engine?*

6.18. There was no evidence before me that Mr Mackiewicz found the incident in January 2000, when he completed a forced landing on one engine at Maitland, South Australia, particularly stressful. The only evidence of distress Mr Mackiewicz may have suffered as a result of that incident was in relation to Mr Kym Brougham's reaction to the incident afterwards. The calmness and professionalism evident in Mr Mackiewicz's voice during radio transmissions on 31 May 2000 suggest that he was still in control and had not panicked or otherwise acted inappropriately.

6.19. Mr Cavenagh, the Senior Transport Investigator in charge of the ATSB investigation, argued that Mr Mackiewicz may have mismanaged the right engine as a result of the 'terrifying' situation he found himself in. He said:

> 'Then its in our view that it is entirely reasonable to understand the pilot as soon as the left engine failed, to firewalling the other engine to ensure that he maximises his survivability chances. It's bad enough with something like this happening during the day, but for it to happen at night would be pretty terrifying.' (T3544)

6.20. The ATSB commissioned an analysis of these radio transmissions by Dr Maurice Nevile of the Research School of Social Sciences at the Australian National University. Dr Nevile's report is part of Mr Cavenagh's evidence, Exhibit C213. Dr Nevile is described as an applied linguist and interaction analyst, whose PhD research involved language and interaction in airline cockpits.

6.21. Dr Nevile found nothing unusual or significant in the Mayday transmission or subsequent transmissions (p14). He had been asked by the ATSB 'whether there is anything that could be considered consistent with a change in workload, attentional focus, stress, anxiety or similar mental state'. He found no such evidence.

6.22. The radio transmissions were also analysed by Ms Jennifer Elliott who is described as a Consultant in Forensic Speech Analysis. Ms Elliott concluded that she found no sign of 'change of workload, attentional focus, stress, anxiety or similar mental state' until the transmission immediately before the Mayday call, after which she found 'intermittent' signs of those conditions which, she said, 'one would expect after finding oneself in the situation that the pilot communicated to ATC in his Mayday call' (p14).

6.23. On the basis of this evidence, there is nothing to justify the ATSB conclusion that MZK had suffered a catastrophic failure of the left engine at 1847:15, about 14 minutes earlier, and that, as a result of such a 'change of workload, attentional focus, stress' etc, Mr Mackiewicz inadvertently overboosted the right engine thereby damaging it.

7. Flights after final service before Flight 904

7.1. 30 May 2000

On 30 May 2000, MZK was flown from Port Lincoln to Whyalla by Mr Ben Auld, a relatively new pilot at Whyalla Airlines who had not had sufficient training in the Chieftain aircraft to operate a RPT flight. Mr Auld had flown to Port Lincoln in another aircraft to collect MZK, which had just undergone a routine Check 2 and Check 3 service.

7.2. During the first flight of each day, pilots were required to fill out a form giving information about the performance of their aircraft in general, and making a note of particular readouts from instruments during the 'cruise' phase of the flight. Exhibit C151 is a bundle of those documents kept by Whyalla Airlines, and was referred to as the 'Trend Monitoring Data'.

7.3. The Trend Monitoring Data for 30 May 2000 was filled out by Mr Auld in relation to the trip from Port Lincoln. Of particular interest is that he noted that the fuel flow rates were 12 gallons per hour on the left engine and 8 gallons per hour on the right engine, and that the EGT (exhaust gas temperature) for the left engine was 1600°F and 1410°F on the right engine (Exhibit C151).

7.4. In explaining what happened, Mr Auld said:

> 'Then your job is to set the engines closer to the desired power settings, and I had set the left engine and that was set up at the correct power settings, and on setting the right engine I had a slow to indicate or a slow raising EGT, the exhaust gas temperature and on leaning to the similar point with the mixture control on the right engine, I leaned slightly past the equivalent point on the other engine - if you can imagine the quadrant for the controls - and for a spilt second the engine ran slightly off song and I immediately richened it up to the same position as the left engine and that was giving smooth running and correct power settings and no problems with CHT or oil pressure or anything like that. I then noted that the EGT was a little bit lower and also the fuel flow was a little bit lower, but it's my understanding that the fuel flow gauges in a Chieftain are not fuel flow gauges, they are fuel pressure gauges that give a derived approximate fuel flow.' (T3603)

7.5. When setting the engine parameters for various phases of a flight, pilots refer to 'peak', a reference to a point indicated on the EGT gauge where an adjustment of the air/fuel ratio (the 'mixture') achieves a maximum reading. This point is reached when the maximum energy is released by the mixture for a given fuel flow, and the engine is then adjusted so that the engine is operating at a temperature 'rich of peak' (where

(Signed)

the fuel flow is increased leading to a drop in EGT below the peak) or 'lean of peak' (where the fuel flow is decreased leading to the same result). If the maximum EGT allowable (1650°F) is reached and the EGT still has not peaked, or if the EGT will not advance to the usual level, then this is referred to as being 'unable to achieve peak'.

7.6. Mr Auld said that he was unable to achieve peak on the right engine. He said that, on this occasion, the engine went 'off song' for a split second, so he did not lean the mixture any further (T3603), but rather he enrichened the mixture to the same setting at which he had already set the left engine. This tends to suggest that Mr Auld leaned the right engine beyond 50° lean of peak (not having achieved peak) to the extent that the engine began detonating.

7.7. Whether running the right engine at such a low fuel flow caused damage to the No.6 piston can only be a matter for speculation. At least one experienced pilot, Mr David Usher, formerly Chief Pilot and Maintenance Controller at Whyalla Airlines suggested that it did (T1686).

7.8. Mr Auld said he discussed the issue with Mr Brougham when he landed in Whyalla, and he said that they would monitor the situation during the next flight.

7.9. Mr Auld and Mr Brougham then flew MZK from Whyalla to Adelaide on a normal RPT flight (Flight 903). Although Mr Auld was unable to recall the readings during that later flight, he recalled the flight generally as having been 'uneventful' (T3605). Mr Brougham recalled that all the instrument readings were normal during that flight (T2362). He disputed the accuracy of the readings recorded by Mr Auld during the earlier flight. He pointed out that the fuel flow readings of 8 gallons per hour for the right engine and 12 gallons per hour for the left engine were inconsistent with the facts that:

- The EGT on the right engine was 1410°F, 190°F lower than the left.
- The amount of fuel added when they refuelled before the next flight was slightly higher than average, and was roughly equal on each side.
- It is 'almost inconceivable' that he would have been able to achieve 155 knots indicated air speed if the engine was running so lean of peak that the fuel flow was 8 gallons per hour. (T2361)

Mr Brougham's conclusion was that Mr Auld had wrongly recorded the flight data (T2361). It is not possible for me to form any clear conclusion about that. The fact remains that Mr Auld did lean the right engine until it ran roughly.

7.10. Mr Brougham said that he monitored the EGT carefully during Flight 903 and noted nothing abnormal. He said the EGT went to 1600°F 'quite easily', in contrast to Mr Auld's experience when he couldn't get it above 1410°F (T2362).

7.11. On the return journey from Adelaide to Whyalla on 30 May 2000 (Flight 904), no flight data was recorded as it was only required once daily. The initials 'C.T.' on the sheet indicate that the pilot was Mr Chris Thompson. Mr Thompson was unable to recall anything of significance arising during that journey (T3827). Mr Thompson said that at no time did he operate MZK lean of peak (T3828).

7.12. The only other evidence I have concerning the return flight comes from two passengers, Mr Jeffrey Raymond and Mr Kym Fewster. Both of these men noticed that the engines appeared to be 'working hard', to the extent that they discussed the matter (see Exhibit's C21a, C22a). Mr Raymond said:

> 'The engines were revving higher (than usual) and that it was struggling to stay in the air.' (Exhibit C21a, page 2)

Based as it is upon the subjective experience of two laymen, who both had hindsight of the subsequent tragedy, I am unable to find, that there was anything abnormal about this flight.

7.13. <u>31 May 2000</u>

On 31 May 2000, MZK flew from Whyalla to Adelaide, and then on a charter flight from Adelaide to Port Pirie, leaving Adelaide about 3:15pm. Mr Mackiewicz was the pilot for the latter journey. Mr Mackiewicz told Mr Damien McQueen, one of the passengers, that after taking them to Port Pirie, he would fly to Whyalla, rest for a while, then fly to Adelaide (Flight 903), return to Whyalla (Flight 904), then fly to Port Pirie to collect them and fly them back to Adelaide (Exhibit C26a, page 1-2). Mr McQueen noticed nothing untoward during the flight.

7.14. Another passenger on the charter flight, Mr Peter Ward, noticed nothing untoward during the journey to Port Pirie, but he thought that the engine was 'revving' louder than usual as it took off from Port Pirie. He said that the engine was 'surging'. He said that once the plane was airborne, the noise settled down (T1661-2). For the same reasons, this evidence is insufficiently clear to justify a finding that there was anything abnormal about this flight.

7.15. Flight 903 from Whyalla to Adelaide in MZK left Whyalla just after 5:00pm on 31 May 2000, and arrived in Adelaide shortly after 6:00pm. Most of the passengers noticed nothing amiss (Mr Wong Exhibits C24a&b, Ms Barnett Exhibit C25a, Ms Franklin Exhibit C28a, Ms Spronk Exhibit C29a and Ms Westlake Exhibit C30a).

7.16. Dr Brian Parkinson is a radiologist who regularly travelled to Whyalla and other places in aircraft similar to MZK. Dr Parkinson said that soon after takeoff he could smell an 'electrical burning smell' in the cabin. He became so concerned that he looked under the seat for a lifejacket (T1911), but of course the aircraft was not equipped with them. Dr Parkinson also noticed that the engines were 'surging' a lot during the latter third of the flight. This also made Dr Parkinson 'quite anxious' (T1912). He accepted that this noise might have been due to the engines not being completely synchronised.

7.17. Dr Parkinson said that after the flight, he saw Mr Kym Brougham looking intently at the tail of the aircraft. Mr Brougham said he had no memory of having done so (T2346).

7.18. Mrs Margaret Morgan also noticed a 'burning smell' in the aircraft. She said that there was no mention of it in the aircraft, and she noticed nothing else that was amiss during the flight (Exhibit C200a, page 1).

7.19. Mr Kym Brougham denied allegations by Drs Durairaj and Chisholm that he and Mr Mackiewicz had an argument at Adelaide Airport about being late (T2882-3). He pointed out that the flight was not late (T2542). He said that Mr Mackiewicz did not mention any problems with the aircraft to him that night (T2346).

(Signed)

7.20. Issues, Discussion and Conclusions

7.21. *Did the right engine of MZK sustain damage on 30 May 2000 when operated lean of peak by Mr Ben Auld on a journey from Port Lincoln to Whyalla?*

7.22. It is not possible to form a conclusion as to whether MZK sustained any damage during the flight on 30 May 2000 when piloted by Mr Auld. There is no reliable evidence of any engine malfunction in MZK after that flight, and Mr Kym Brougham was monitoring the engine carefully, looking for any sign of a problem. It is possible that some damage was caused during that flight, but this can not be demonstrated on the evidence.

7.23. *Witnesses on the charter flight noticed that an engine was 'revving' louder than usual, and was surging. A witness also noticed an engine surging during Flight 903, and two witnesses also noticed a burning smell during that flight. Does this evidence suggest that one of the engines of VH-MZK was malfunctioning even before Flight 904 commenced?*

7.24. It is not possible to form a conclusion that either of the engines in MZK were malfunctioning during Flight 903. The fact that Dr Parkinson noticed that the engines were surging more than usual (he was an experienced passenger) suggests that one of the engines may have lost power, but this was not evident during takeoff and climb during Flight 904. The 'burning smell' is also a mystery, and none of the experts who gave evidence suggested a cause for it.

(Signed)

8. Refuelling

8.1. When MZK arrived in Adelaide just after 6:00pm on 31 May 2000, Mr Leslie Allen was waiting at the General Aviation area to refuel it. Mr Allen was employed as a refueller by BP Air Pty Ltd. Mr Allen said that the pilot left a note on the dashboard against the windscreen saying 'full mains advise split'. This told him to fill both main tanks of the aircraft (not the auxiliary tanks), and advise how much fuel was put in each tank (T1300-1).

8.2. Mr Allen said that once the propellers ceased rotating, he parked his truck in front of the aircraft and, once the passengers had disembarked, filled the main tanks to capacity. He wrote the fuel figures on the nose wheel of the aircraft with chalk. He said that because he was busy, he forgot to make a note of the quantity in his notebook (T1305).

8.3. Mr Allen's notebook (Exhibit C69e) reads as follows:

	7735
MZK	218
1445	7953
CMD	165
1545	8118
KEZ	300
2050	8418
MZK	234
1800	8642

It can be seen that the last two entries are out of order. The aircraft VH-KEZ was refuelled at 8:50pm, and MZK at around 6:00pm. The larger figures in the right hand column should have been taken from an instrument on the tanker called a 'totalisator', a sealed instrument which maintains a running total of the quantity of fuel delivered by the tanker throughout its life.

(Signed)

8.4. As a result of Mr Allen's notes being out of order, the totaliser figures after 1545 are completely wrong. If what Mr Allen says is true, the figures should be:

	7735
MZK	218
1445	7953
CMD	165
1545	8118
MZK	234
1800	8342
KEZ	300
2050	8642

8.5. The incorrect figures were then transposed into the company documentation (the Aviation Fuel Delivery Receipts Exhibit C69b, C69f and C69g), so the entries in those documents are incorrect as well. As to the last figure for KEZ, Mr Allen was not even able to confirm that this was the amount delivered - merely that this was the usual order (T1375-6).

8.6. Mr Allen said that he did not realise his mistake until sometime after 9:30pm (T1316), more than an hour after he heard that a plane had ditched, when Mr Kym Brougham spoke to him on the telephone. Mr Brougham had asked him if he had refuelled MZK and, since there was no entry in his notebook at that time, he told Mr Brougham that he had not. Mr Brougham became upset, saying that Mr Mackiewicz must have forgotten to refuel. Mr Allen said that during the conversation, he suddenly remembered that he had put 234 litres in MZK, and then told Mr Brougham so (T1306-7).

8.7. After his conversation with Mr Brougham, Mr Allen then made the entries into the notebook, and proceeded to calculate the running totals in the manner I described earlier.

8.8. I have considerable difficulty with Mr Allen's evidence. Of course his record-keeping is a shambles and not to be relied upon. Having regard to the fact that he had heard about a ditching at 8:30pm, and had called his supervisor, Mr Paul Sheidow, who came in to work (T1343), it is surprising that Mr Allen did not realise that he had refuelled MZK until sometime after 9:30pm. Mr Sheidow said that they ascertained from the control tower at 9:20pm that the aircraft concerned was MZK (T2214). One

(Signed)

would think that the first question between the two men arising from that would have been ‘did you refuel it?’

8.9. Mr Brougham confirmed that, after several attempts, he spoke to Mr Allen who initially denied refuelling MZK, and then purported to recall that he had supplied 232 litres. Not surprisingly, Mr Brougham was suspicious of this (T2548).

8.10. Having eventually recalled that he supplied 234 litres, Mr Allen asserted to Detective Duval on 8 March 2002, almost two years after the event, that he had a ‘vivid’ memory that he put 119 litres in the left main tank of MZK and 115 litres in the right main tank, and that he wrote these figures on the nose wheel (Exhibit C69a, page 5).

8.11. After the conversation with Mr Brougham, Mr Allen said that he then checked the totalisator, and calculated back from the reading, taking into account 300 litres for KEZ. He reached a total of 232 litres, but remembered that it was actually 234 (Exhibit C69a page 5, T1348).

8.12. I also have considerable difficulty with Mr Allen’s assertion that his memory returned to him in such detail after the event.

8.13. Both Mr Allen (T1303-4) and Mr Sheidow (T2195) told me, and I accept, that Mr Allen could not have put Jet A1 fuel in MZK, as the Jet A1 nozzle would not have fitted into MZK’s fuel filler pipes, since they had been fitted with ‘orifice plates’ which are specifically designed to prevent this from happening. The trigger mechanisms are also different. In order to further reduce the risk of incorrect fuel being supplied, there is clear signage on both the tanker and on the wings of the aircraft indicating what fuel is appropriate (T2196-7).

8.14. I heard evidence from Mr Sheidow that he reconciled both the Avgas and Jet A1 tankers that night.

8.15. Mr Sheidow said that when he spoke to Mr Allen, having established that the Avgas reconciliation was ‘out’, Mr Allen ‘remembered’ that he had refuelled MZK and gave him the wing split (T2223). Mr Sheidow’s memory was rather imprecise as to the details of these conversations, but I find that the combined effect of Mr Brougham’s and Mr Allen’s evidence is sufficient to satisfy me that Mr Allen first remembered that he refuelled MZK during his conversation with Mr Brougham at sometime after

9:30pm. As I have said, this evidence is surprising, but it is the only way that the various accounts of what occurred can be reconciled.

8.16. With Mr Allen having 'remembered' that he had supplied 234 litres of Avgas to MZK, the reconciliation then balanced. Mr Sheidow said that another officer of BP Air, Mr Dominic Gerace, performed an 'independent' reconciliation on 1 June 2000, and that also balanced (T2226).

8.17. Mr Sheidow told me that samples were taken from the trigger nozzle, directly from the tank, and from the storage tank from which the tanker was filled, and testing of these samples revealed no abnormalities (T2240-44). He also explained that the fuel is extensively tested at various points on its journey from Kwinana, Western Australia, where it is manufactured, to Adelaide (T2251-2255).

8.18. The ATSB final report (Exhibit C97) records:

> 'A witness who was waiting at Adelaide Airport to meet a passenger on the incoming flight from Whyalla later reported that although he saw a refuelling tanker stopped near the Whyalla Airlines aircraft when it arrived, he did not believe the aircraft was refuelled. He said that although his view was partially obstructed while waiting for the passenger's luggage to be unloaded, he noticed the tanker drive away after what he believed to have been no more than about four minutes and surmised that the aircraft had not been refuelled. The manager of the fuel facility said that it typically took a total of 10-15 minutes to complete the refuelling process for a Chieftain aircraft. The refueller reported that only 3-4 minutes was actually taken with pumping fuel, the remaining time being taken with associated tasks such as connecting earth leads and preparing hoses.'
>
> (Exhibit C97, p33)

8.19. The ATSB also reported:

> 'Refuelling procedures at Adelaide Airport were discussed with other company pilots. The information they provided included the following:
>
> - Some considered that time pressure during turn-arounds (see also section 1.19.5) could result in a pilot forgetting to check that the aircraft had been refuelled.
> - One pilot had seen other pilots depart without checking the front tyre for the amount of fuel added.
> - One pilot had been ready to depart on four or five occasions when he found out that the aircraft had not been refuelled.
> - Another pilot had departed Adelaide without the aircraft having been refuelled and elected to return to Adelaide to refuel.
> - Fuel tank caps had been left off on a few occasions.' (Exhibit C97, p33-34)

8.20. The ATSB investigators considered whether, even if MZK had not been refuelled immediately before Flight 904, there still would have been enough fuel to reach Whyalla. The report states:

> 'Calculations for the accident flight based on a 'fuel on board' total of 131 L ex Adelaide indicated that the aircraft would have had 21 L remaining on arrival at Whyalla. However, that did not account for true airspeeds less than the published figures, the additional track miles flown during departure from Adelaide, and any variation in engine operation and leaning procedure that the pilot may have used. The same calculation using data from the Whyalla Airlines Operations Manual indicated that there would have been a shortfall of about 2 L.
>
> **Observations:**
>
> - The wreckage examination did not permit a conclusion to be drawn regarding the amount of fuel on board the aircraft at impact.
> - It was not possible to establish categorically that the aircraft had been refuelled after arriving at Adelaide from Whyalla. However, on the information available, the likelihood is that the aircraft was refuelled.
> - No anomalies were found regarding fuel quality.
> - The fuel tank selection established from wreckage examination was consistent with normal operation whereby the engines were being fed from the main fuel tanks.
> - The observation of fuel in the boost pump, firewall shut-off valve, and filter bowl for the left engine indicated a high probability that fuel was available to the left engine when it ceased operating. Impact damage negated similar information being available from these components for the right engine.'
>
> (Exhibit C97, p34)

8.21. It is also noted that Mr Sargeant, the ATSB investigator who prepared the draft ATSB report, concluded that fuel quantity or quality were not considered to have been contributing factors (Exhibit C89a, p7).

8.22. Mr Kym Brougham made similar calculations, and concluded that MZK would have reached Whyalla even if it had not been refuelled immediately before Flight 904 (T2549).

8.23. Mr Brougham also pointed out that the fuel gauges, which were part of the wreckage inspected as part of the inquest, indicated that the fuel tanks were just over half full when MZK hit the water. He said that he believed that the gauges would have frozen in those positions upon impact, and would therefore give an accurate picture of the fuel on board at that point, although he could not be absolutely certain about that (T2550).

(Signed)

8.24. Issues, Discussion and Conclusions

8.25. *Was MZK refuelled immediately before Flight 904?*

8.26. I have considerable reservations about the reliability of Mr Leslie Allen as a witness. If his evidence had been the only evidence available, I would have been unable to find with any certainty that he did refuel MZK before Flight 904. However, having regard to the evidence of Mr Sheidow, and the detailed records he produced, I find on the balance of probabilities that between 232 and 234 litres of fuel was supplied to MZK by Mr Allen before Flight 904. I note that none of the parties who were represented at the inquest submitted to the contrary to this proposition.

8.27. I am fortified in that conclusion by the findings I have already made about Mr Mackiewicz's competence and professionalism as a pilot. Had MZK not been refuelled, Mr Mackiewicz would have become aware of it quite quickly, and he would not have taken off, or if he did he would have turned back, as soon as he became aware that he may not have sufficient fuel to reach Whyalla.

8.28. *If not, did MZK have enough fuel on board to reach Whyalla in any event?*

8.29. Calculations made by the ATSB investigators, and by Mr Kym Brougham, suggest that MZK would have had sufficient fuel to reach Whyalla even if it had not been refuelled immediately before Flight 904 (see Exhibit C97, p34 and Mr Brougham's evidence at T2549).

8.30. *Were there any impurities or abnormalities in the fuel which would have caused or contributed to the failure of either of MZK's engines?*

8.31. The evidence of Mr Sheidow satisfies me that it is possible to trace the quality of the fuel delivered to MZK before Flight 904 back to an original batch manufactured at Kwinana in Western Australia and that this batch of fuel was tested at various critical control points along the way and showed no impurities or abnormalities. In addition, tests of fuel taken that night from the same tanker disclosed no impurities or abnormalities. The ATSB also took fuel from MZK's left auxiliary fuel tank after the wreckage was recovered, and again this fuel disclosed no impurities or abnormalities.

8.32. On the basis of this evidence, I find that there were no impurities or abnormalities in the fuel delivered to MZK before Flight 904 which would have caused or contributed to the failure of either of MZK's engines. Inherent in that, is a finding that the correct fuel was delivered to MZK that evening.

8.33. There have been other tragedies as a result of a refuelling company delivering Jet A1 fuel, rather than Avgas, to a piston-engine aircraft. Having regard to the various mechanisms which AirBP had taken to prevent this occurring, such as the size of the filler pipes, the difference in the trigger mechanisms, the signage, and to the fact that Mr Sheidow reconciled both the Avgas and Jet A1 fuel records that evening, it is extremely unlikely that incorrect fuel was delivered.

9. The ATSB investigation

9.1. As I have already said, the wreckage of MZK was lifted from the water of Spencer Gulf on 9 June 2000, and taken into the custody of the ATSB. A team lead by Senior Transport Safety Investigator Mr Barry Sargeant was appointed to perform the investigation. The wreckage was transported to the ATSB's premises in Canberra.

9.2. In a statement dated 6 November 2000, which Mr Sargeant very helpfully prepared before the draft ATSB report was released, Mr Sargeant drew the following conclusions:

- The damage to the aircraft was consistent with it entering the water in a glide altitude (page 6);
- The aircraft was considered to have been capable of controlled non-powered flight immediately prior to the accident (page 6);
- It was not considered at that stage that fuel quantity or quality were contributing factors (page 7);
- The left engine had stopped following a fatigue fracture of the crankshaft at the No.6 connecting rod journal. The fracture initiated below the surface of the forward journal radius. There was a small 'radial' crack from the surface to the initiation point of the type created by thermal stresses on the journal surface (page 7);
- The No.6 connecting rod 'big end' bearing had failed. Extensive thermal cracking was seen on the entire journal surface (page 7);
- In the right engine there was a hole near the top of the No.6 piston which allowed combustion gases to bypass the piston rings. The piston material had melted creating the hole (page 7).

(Exhibit C89a)

9.3. Mr Sargeant advised that on 30 October 2000, the ATSB made the following Air Safety Recommendations to the CASA:

Recommendation R20000248

The Australian Transport Safety Bureau recommends that the Civil Aviation Safety Authority amend Civil Aviation Order section 20.11 paragraph 5.1.2 so that the requirement to carry life jackets or equivalent flotation devices is not restricted to aircraft authorised to carry more than nine passengers.

Recommendation R20000249

The Australian Transport Safety Bureau recommends that the Civil Aviation Safety Authority ensure that Civil Aviation Orders provide for adequate emergency and life saving equipment for the protection of fare-paying passengers during over-water flights

(Signed)

where an aircraft is operating beyond the distance from which it could reach the land will all engines inoperative.

Recommendation R20000250

The Australian Transport Safety Bureau recommends that the Civil Aviation Safety Authority alert operators of aircraft equipped with turbo-charged engines to the potential risks of engine damage associated with detonation, and encourage the adoption of conservative fuel mixture leaning practices.

(Exhibit C89c)

9.4. Draft ATSB report

On 4 April 2001, a draft report detailing the results of the ATSB investigation was forwarded to 'interested parties', organisations and/or individuals who were directly involved in the accident or its aftermath. A copy was supplied to me as such a person (the draft report is now Exhibit C73d).

9.5. The draft report was written by Mr Barry Sargeant and his team. The process was that the report was circulated to interested parties who were invited to comment on its contents, and to provide evidence which would justify amendment of the report (T3655).

9.6. Without going through the draft report in detail, it is appropriate to observe that it is a substantially different document from the final ATSB report (Exhibit C97).

9.7. The Executive Summary of the draft ATSB report is as follows:

> 'On the evening of 31 May 2000 Piper Chieftain, VH-MZK, was being operated as Flight WW904 on a regular public transport service from Adelaide to Whyalla SA, carrying one pilot and seven passengers. After being radar vectored a short distance to the west of Adelaide for traffic avoidance purposes, the pilot was cleared to track direct to Whyalla at 6,000 ft. A significant proportion of the track from Adelaide to Whyalla passed over the waters of St Vincent Gulf and Spencer Gulf.
>
> The pilot of MZK subsequently reported to Adelaide Flight Information Service that the aircraft was 35 NM SSE of Whyalla, at top of descent from 6,000 ft. Five minutes later the pilot gave a MAYDAY report to FIS indicating that the aircraft had experienced two engine failures, that there were eight persons on board and that he was going to have to ditch, but was trying to get to Whyalla. He reported that his position was about 15 NM off the Whyalla coast and requested that help be sent, and for his company to be advised.
>
> A search and rescue operation subsequently located two deceased persons and a small amount of wreckage early the following morning in Spencer Gulf, near the last reported position of the aircraft. The aircraft was located some days later on the sea-bed, together with five deceased occupants. One passenger remains missing.

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The wreckage of the aircraft was recovered for examination. The left engine was found to have incurred catastrophic mechanical damage, whereas the right engine was found with mechanical damage of a dimension sufficient to significantly affect its operation. Although the damage exhibited in each engine differed considerably, further specialist analysis determined that the damage to both engines was consistent with the effects of abnormal combustion. The management policy of the airline was found to encourage fuel leaning practices which had the unintended consequence of inducing engine damage.

Multi-engine land aircraft authorised to carry nine passengers or less on regular public transport or charter operations were not required to be equipped with life jackets or equivalent flotation devices unless the aircraft was operated over water, and at a distance from land of greater than 50 NM. The Adelaide to Whyalla track was less than 50 NM from land. The investigation found it likely that the occupants of the Chieftain would have had sufficient time to don life jackets had they been provided, increasing their survival chances.

During the course of this investigation the Australian Transport Safety Bureau has already issued three recommendations to the Civil Aviation Safety Authority addressing the following safety deficiencies: fuel mixture leaning practices for turbo-charged engines; the carriage of life jackets; and the provision of adequate emergency and life saving equipment for the protection of fare-paying passengers during over-water flights.'

(Exhibit C73d, p. v)

9.8. The summary of the failure analysis of the two engines in the draft report is as follows:

'The failure and/or malfunction of the engines fitted to Whyalla Airlines aircraft, VH-MZK, resulted in the aircraft ditching into Spencer Gulf.

The left engine failed after the crankshaft fractured at the No.6 connecting rod journal. Fracture occurred as a result of fatigue crack growth. Cracking in the hardened surface zone of the journal, created by thermal strains developed in the journal surface following the failure of the connecting rod journal bearing, was responsible for fatigue crack initiation.

The left propeller was recovered with the blades in the feathered position. The lack of blade damage indicated that the propeller was feathered at the time of ditching.

Examination of the right engine revealed that component failure was restricted to the creation of a hole in the No.6 piston by localised melting. The rotating components of the engine were free to move.

The right propeller was recovered with the blades in the feathered position. All three blades been deformed by out-of-plane bending loads during ditching. Each blade was bent towards its thrust side. It was evident that the No.1 blade had been subjected to the highest bending load. A strip-down examination of the propeller revealed that the forces developed during blade bending had fractured the lip of the No.1 blade bearing preload plate. These forces also resulted in the twisting of the No.1 blade to an extent that caused the blade pitch change fork mechanism to be deformed.

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The nature of the damage displayed by the right propeller indicated that the propeller blades were in normal operating pitch setting at the time of ditching. Blade movement is likely to have occurred at some time after ditching. The engine and propeller had separated from the airframe during impact with the water.

Analysis of the engine physical evidence revealed that the modes of engine failure involved conditions of abnormal combustion. However the modes of abnormal combustion were different for both engines and the outcome of abnormal combustion depended on a complex interaction of other engine operational and assembly factors.

The significant factors that resulted in the failure of the left engine were:

- The accumulation of lead oxides on the crowns of pistons and cylinder head surfaces. The nature of these deposits was such that localised melting of the deposits occurred. The temperature of the molten deposits was sufficient to create regions of incandescence.
- Incandescent surface deposits acted as sites for preignition.
- The advance of ignition timing caused by preignition increased the magnitude of the gas firing loads, increasing the loads on the connecting rod assemblies.
- The bearing shell retention forces were reduced by the inclusion of a copper-based anti-galling compound during engine assembly.
- The combination of increased bearing loads and decreased bearing shell retention forces resulted in the movement of the bearing shells and their destruction.
- Continued rotation of the connecting rod big end housing against the crankshaft journal, following the loss of the bearing shells, resulted in the heating of the hardened surface of the journal and the creation of thermal cracks.
- Fatigue cracking initiated at the site of a thermal crack under bending loads created by gas firing. Fatigue cracking initiated approximately 50 flights prior to the accident.

The abnormalities in combustion that led to the failure of the left engine occurred during operation at least 50 flights prior to the final flight. The right engine was not affected in a similar manner.

The significant factors that were involved in the failure/malfunction of the right engine were:

- Detonation of the combustion end-gas.
- Disruption of the gas boundary layers on the piston crowns and cylinder head surface (gas boundary layers create a high thermal resistance limiting heat transfer to engine components).
- Increased heat transfer to a localised region of the pistons.
- Localised melting of the pistons.

The combustion conditions that led to the end-gas detonation of the right engine did not result in the same effects in the left engine. It is possible that the right engine was operated under different conditions to the left engine.

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Examination of failures in engines of a similar type revealed that the deposition of lead oxides that had created regions of incandescence was not restricted to the engines from MZK. It was also found that a copper-based anti-galling compound had been used in the assembly of connecting rod bearings of an engine that was subsequently shut down inflight following the failure of a connecting rod big end bearing.

Issues arising from this analysis are:

- The use of anti-galling compounds in the assembly of connecting rod big end bearings, and the potential effect on the magnitude of bearing insert retention forces.
- The deposition of a particular form of lead oxide that melts under combustion conditions to form incandescent sites in the combustion chamber. Operating practices should be established, and clearly communicated, that prevent the deposition of this form of lead oxide.
- The need for clarification of the conditions under which end-gas detonation occurs in Lycoming TIO-540 and LTIO-540 engine installed in Piper PA 31-350 aircraft.

(Exhibit C73d, Attachment A, p1-3)

9.9. Whyalla Airlines Fuel Leaning Practices

The draft report criticises Whyalla Airlines in that they were found to 'encourage fuel leaning practices which had the unintended consequence of inducing engine damage'. The body of the report reads:

'During the investigation all company pilots were interviewed. The PA31-350 engine handling procedures described by most pilots were generally in accordance with those described by the Manager/Chief Pilot. Most pilots used a mixture setting in cruise that resulted in an EGT 50°F rich of peak.

One pilot had been endorsed on the Chieftain by the Manager, having no previous experience operating turbo-charged engines. He described the technique he had been taught for setting cruise power. Once established at the cruise altitude he would set 29"-30"MP/2200 RPM then lean the mixture until the EGT was lean of peak. He was aware that there was a caution not to operate at more than 1650°F. He said that the procedure he was taught was to operate 50°F lean of peak. He said that he was told that this gave slightly less power but with an improved fuel flow. The pilot said that an EGT of 50°F lean of peak gave EGT's that were still in the green band, but at the top of the band. He indicated that he would not make any adjustments just based on fuel flow indications. If each engine was different it did not matter – he just left the mixtures set at 50°F lean of peak.

The pilot could not recall what the EGT's were generally, but was aware that they were usually at the top of the green scale. He reported that the Manager had told him that other companies operated their aircraft differently, but the pilot was not aware of what those differences were. The same pilot had ferried MZK from Port Lincoln to Adelaide on the day prior to the accident flight (refer para 1.18.4).

Another pilot, who had joined the company at the same time as the accident pilot, said that he was taught by the Manager, who was also the Training and Checking pilot, to

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lean the mixtures in cruise to give an EGT of 50°F rich of peak, but was aware that new pilots were taught differently. He described the company standard operating procedures concerning fuel mixture leaning were "wishy washy". He also believed that the pilot of MZK would have used the same leaning procedure as himself.' (Exhibit C73d, p41-42)

9.10. The draft report acknowledges that Whyalla Airlines' Operations Manual (Exhibit C73h) refers to Report 2046, issued by Piper Aircraft Corporation for 'Aircraft Technical Data' (p38). Report 2046 was one of three such reports produced by Piper for Navajo Chieftain aircraft, i.e. numbers 1750, 2046 and 1208. In fact, 1208 was the correct report for MZK but nothing turns on that - the directions for fuel leaning are the same in both versions.

9.11. The Whyalla Airlines Operations Manual (Exhibit C73h), provides that during the climb phase, the following engine settings should be used:

'Climb

Initial climb speed 110 (knots) until 500_800 feet

Initial climb power 38_40" MAP (manifold pressure) 2400rpm, 30usg/hr (US gallons)

Cruise climb speed 130 knots.

Cruise climb power 36_38"MAP 2400rpm *27 usg/hr or max 1500egt* (Exhaust Gas Temperature)'

(Exhibit C73h, page 39)

9.12. These settings are within the parameters set out in the Pilot Operating Handbook published by Piper Aircraft Corporation, Report LK-1208, published 14 September 1979 (Exhibit C170g). That Handbook prescribes engine operating temperature limits as follows:

CHT (Cylinder Head Temperature)	
CHT normal operating range (green arc on gauge)	100°F to 475°F
CHT caution range (yellow arc on gauge)	475°F to 500°F
CHT limit (red radial on gauge)	500°F
CHT maximum continuous	475°F
CHT maximum desirable for maximum engine life	435°F

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Oil temperature	
Oil temperature normal range (green arc on gauge)	120°F to 245°F
Oil temperature limit (red radial on gauge)	245°F
EGT (Exhaust Gas Temperature)	
EGT normal operating range (green arc on gauge)	up to 1650°F
EGT limit (red radial on gauge)	1650°F

9.13. The Pilot Operating Handbook also sets out the procedure for takeoff and initial climb as follows:

'4.23 TAKEOFF

Normal

While holding the brakes with the mixture and propeller levers full forward, advance the throttles slowly to a manifold pressure of 30 inches of mercury; then continue to advance the throttles at a normal rate and release brakes, but do not allow manifold pressure to exceed 49 inches. Use smooth, steady throttle movements, and avoid rapid opening and closing. Propeller speed for takeoff should be 2575 RPM.

The engines are adjusted to provide 43 inches Hg. manifold pressure at full throttle in standard temperature at sea level. Depending upon an altitude and temperature it is possible to reach higher (up to 49 inches) or lower manifold pressures.

Each engine density controller is set to produce rated takeoff power for the engine. The takeoff power manifold pressure for each engine will not necessarily be the same. However, if the spread in manifold pressure exceeds three inches during a full throttle climb, the density controller settings should be checked and serviced.

At 85 KIAS, rotate to a 10° pitch attitude and allow the aircraft to fly off. Maintain a pitch attitude which will result in acceleration of the aircraft to 95 KIAS at 50 feet. Before airspeed reaches 128 KIAS, retract the landing gear. Continue acceleration to the desired climb airspeed.

4.24 CLIMB

When clearance above obstacles and terrain permits, reduce to Maximum Normal Operating Power by setting the throttles to 40 inches Hg. manifold pressure and the propellers to 2400 RPM. Turn air conditioner on as desired. Lean the mixture to a minimum fuel flow of 30 gallons per hour at a maximum exhaust gas temperature of 1500°F and maximum cylinder head temperature of 475°F. Adjust cowl flaps and mixture as necessary to maintain engine temperatures within limits.

Turn the emergency fuel pumps OFF one at a time, and check fuel gauges and warning lights. At power settings above 75%, maintain the mixture controls in the full RICH position except with Maximum Normal Operating Power setting when the mixture may be leaned as stated in the preceding paragraph.

> Although the maximum approved operating altitude for this airplane is 24,000 feet, under standard atmospheric conditions and at maximum gross weight the multi-engine service ceiling and absolute ceiling are 27,200 feet and 28,300 feet, respectively.'
>
> (Exhibit C170g, sections 4.23 and 4.24)

It can be seen from the above that the Whyalla Airlines Operations Manual specification for climb of 30 usg/hr is the minimum specified in the Pilot Operating Handbook, and the cruise climb specification of 27 usg/hr is below the minimum specified. There is the protective caveat that the EGT should not exceed 1500°F, which is consistent with the specifications quoted above, although, as I will discuss later, Mr Braly said that this was too high, and that detonation was possible within those limits. There is no injunction against operating the engine at mixtures lean of peak.

9.14. On the other hand, Textron Lycoming's Operators Manual (Exhibit C172f) advises that their engines should 'always be operated on the rich side of peak' (Section 3, p6). In a later Service Instruction 1094D (Exhibit C73o), the following message appears:

> 'Textron Lycoming does not recommend operating on the lean side of peak EGT.'
>
> (Exhibit C73o, p6)

9.15. It was unanimous among all the pilots and aircraft operators who gave evidence at the inquest that the Textron Lycoming Operators Manual had never come to their attention (see for example Mr Beattie at T1983 and Mr S Jelinek at T1999). The draft ATSB report points out that Regulation 50E of the Civil Aviation Regulations 1988, sub-regulation (4)(f) places a higher priority on the aircraft manufacturer's instructions to those of the 'component manufacturers', including the engine manufacturer. In those circumstances, Whyalla Airlines cannot be fairly blamed for following Piper Aircraft Corporation's Pilot Operating Handbook leaning procedures.

9.16. I heard further evidence about fuel leaning which calls into question the assertion that fuel leaning to 50°F lean of peak during the cruise phase of flight would have had any deleterious effect on the engines, as alleged in the draft report, in any event. Leaning at higher power settings, in the climb phase of flight is a different matter. I will discuss this matter further when examining the evidence I heard in the United States of America.

9.17. Textron Lycoming's response to draft ATSB report

In a letter dated 23 April 2001, Textron Lycoming responded to the findings of the draft ATSB report. The letter forms part of Exhibit C213. While Textron Lycoming accepted that 'abnormal combustion' was involved in both engine failures, they questioned whether incandescence from combustion chamber deposits was the cause of that. They offered a number of other possible explanations:

- improper spark timing - there was no suggestion that the magnetos had been checked to investigate that possibility;
- spark plug anomalies - there was no mention of the spark plugs being analysed to determine if they were operating properly;
- improper fuel flow to one cylinder causing excessive leaning in that cylinder - there was no mention of the fuel nozzles being examined to investigate that;
- excessive manifold pressure can be caused by improperly set density control valves on the turbochargers - there was no mention of this being examined either.

9.18. Textron Lycoming disputed that abnormal combustion damage would have been caused during the cruise phase of the flight. They pointed out that Whyalla Airlines operated their aircraft at power levels well below the engine operating limits and their 25 years experience led them to doubt that the engines were detonating at those levels.

9.19. Textron Lycoming suggested that the failure of the right engine might have followed the failure of the left. If, after the left engine failed, the pilot advanced the throttle on the right engine to maintain altitude without moving the mixture level to full rich, this could have resulted in abnormal combustion and holed the No.6 piston. This is the first occasion on which this theory was advanced, and it was to be adopted and developed by the ATSB later.

9.20. Textron Lycoming also disputed that the failure of the left engine was due to the anti-galling compound causing a loss of bearing retention at the No.6 connecting rod journal of the left engine. They argued instead that the lining materials in the bearings failed due to abnormal combustion forces, and as each layer of lead, tin and aluminium delaminated, they were forced out the sides of the bearing by normal oil flow, and either caused localised heating of the crankshaft, or they forced direct contact between the conrod and the crankshaft causing a heat crack in the crankshaft.

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9.21. Textron Lycoming pointed out, and I accept the force of this argument, that on this hypothesis, the bearings would have been failing for some time, and the debris from the progressive bearing failure should have been detected at the last 100 hourly inspection, culminating on 30 May 2000, the day before the accident. During that service the oil filters were cut open and inspected, and the suction screens were taken out and inspected (see the evidence of Mr Jones T908 and Mr Parker T939). No such debris was found.

9.22. On 23 May 2001 Mr Barry Sargeant, the Investigator-in-Charge of the MZK investigation, retired from the ATSB, and was replaced by Mr Michael Cavenagh. Mr Cavenagh is another investigator with extensive experience, having trained in the RAAF and later at the ATSB where he has investigated more than 250 accidents, and more than 2,800 incidents.

9.23. <u>The Final ATSB Report</u>
The ATSB investigation proceeded until 19 December 2001 when the final report was published (Exhibit C97).

9.24. Only five days before publication, on 14 December 2001, a Piper Navajo Chieftain aircraft, VH-JCH, owned by Sharp Aviation Pty Ltd, suffered a crankshaft failure which was remarkably similar to the failure of the left crankshaft in MZK. Fortunately, the other engine continued to operate, and the aircraft landed safely. I will detail this incident again, later in these findings.

9.25. The Executive Summary of the final report, as amended at the request of Mr Cavenagh when he gave evidence (T3574-78), accurately summarises the detailed findings in the report as follows:

> 'On the evening of 31 May 2000, Piper Chieftain, VH-MZK, was being operated by Whyalla Airlines as Flight WW904 on a regular public transport service from Adelaide to Whyalla, South Australia. One pilot and seven passengers were on board. The aircraft departed at 1823 central Standard Time (CST) and, after being radar vectored a short distance to the west of Adelaide for traffic separation purposes, the pilot was cleared to track direct to Whyalla at 6,000 ft. A significant proportion of the track from Adelaide to Whyalla passed over the waters of Gulf St Vincent and Spencer Gulf. The entire flight was conducted in darkness.
>
> The aircraft reached 6,000 ft and proceeded apparently normally at that altitude on the direct track to Whyalla. At 1856 CST, the pilot reported to Adelaide Flight Information Service (FIS) that the aircraft was 35 NM south-south-east of Whyalla, commencing

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descent from 6,000 ft. Five minutes later the pilot transmitted a MAYDAY report to FIS. He indicated that both engines of the aircraft had failed, that there were eight persons on board and that he was going to have to ditch the aircraft, but was trying to reach Whyalla. He requested that assistance be arranged and that his company be advised of the situation. About three minutes later, the pilot reported his position as about 15 NM off the coast from Whyalla. FIS advised the pilot to communicate through another aircraft that was in the area if he lost contact with FIS. The pilot's acknowledgement was the last transmission heard from the aircraft. A few minutes later, the crew of another aircraft heard an emergency locator transmitter (ELT) signal for 10-20 seconds.

Early the following morning, a search and rescue operation located two deceased persons and a small amount of wreckage in Spencer Gulf, near the last reported position of the aircraft. The aircraft, together with five deceased occupants, was located several days later on the sea-bed. One passenger remained missing.

On 9 June 2000, the wreckage of the aircraft was recovered for examination. Aside from the engines, no fault was found in the aircraft that might have contributed to the accident. Both engines had malfunctioned due to the failure of components of the engines.

The crankshaft of the left engine fractured at the Number 6 connecting rod journal. Fatigue cracking was initiated by the presence of a planar discontinuity in the journal surface. It was evident that the discontinuity had been caused by localised thermal expansion of the nitrided journal surface following contact with the edge of the Number 6 connecting rod big end bearing insert. The crankshaft failed approximately 50 flights after fatigue crack initiation.

The Number 6 bearing insert was damaged during engine operation through the combined effect of:

- high bearing loads created by lead oxybromide deposit induced preignition, and
- lowered bearing insert retention forces associated with the inclusion of an anti-galling compound between the bearing inserts and the housings.

Fatigue cracking in the Number 6 connecting rod big end housing had developed following the gradual destruction of the bearing insert. The left engine probably continued to operate for 8-10 minutes before the final disconnection of the Number 6 journal of the crankshaft. The Number 6 big end connecting rod housing failed during that period. It is likely that the engine would have displayed signs of rough running and some power loss during this time. The final disconnection of the crankshaft resulted in a loss of drive to the magnetos, fuel pump, camshaft and, consequently, the sudden stoppage of the engine. The left propeller was in the feathered position when the aircraft struck the water, confirming that the engine was not operating at that time.

The physical damage sustained by the right engine was restricted to the localised melting of the Number 6 cylinder head and piston. The piston damage had allowed combustion gases to bypass the piston rings. The overheating of the right engine combustion chamber components was a result of changes in heat transfer to cylinder head and piston surfaces created by combustion end-gas detonation. The carbonaceous nature of the residual deposits on the piston crowns indicated that detonation had occurred under a rich fuel-air mixture setting. Rich mixture settings are used with high engine power settings.

The damaged piston would have caused a loss of engine oil and erratic engine operation, particularly at higher power settings. Engine lubrication was still effective at impact, indicating that oil loss was incomplete and that the piston holing occurred at a late stage of the flight.

Examination of the right propeller indicated that the blades were in a normal operating pitch range (i.e. not feathered) when the aircraft struck the water. It could not be confirmed that the right engine was operating when the aircraft struck the water, although it most probably was operating when radar contact was lost as the aircraft descended through 4,260 ft when 25.8 NM from Whyalla.

The aircraft was not fitted with a Flight Data Recorder (FDR) or a Cockpit Voice Recorder (CVR), nor was it required to be. Analysis of recorded radar data confirmed that the aircraft performed normally during the flight until the latter stages of the cruise segment when the speed gradually decreased. Speed variations, accompanied by track irregularities, then became more pronounced. Analysis of recorded voice transmissions revealed that the propeller (and engine) RPM during the climb from Adelaide was 2,400. The RPM was 2,200 after the aircraft levelled at 6,000 ft. These were normal climb and cruise engine settings used by the company and the performance achieved by the aircraft during these segments was consistent with normal engine performance. Just prior to the commencement of descent, an RPM of 2,400 was identified. That was not a normal engine power setting for that stage of the flight.

The aircraft speed and propeller RPM information, coupled with the engine failure analysis, was consistent with the following likely sequence of events:

- The power output from the left engine deteriorated during the first third of the cruise segment of the flight after the crankshaft and later the Number 6 connecting rod big end housing had fractured. The engine ceased operating 8-10 minutes later.
- In response to the failure of the left engine, the pilot increased the power setting of the right engine.
- Increased combustion chamber component temperatures via detonation within the right engine led to the Number 6 piston being holed. That resulted in the erratic operation of the right engine with reduced power and controllability and left the pilot with little alternative but to ditch the aircraft.
- The double engine failure was a dependent failure.

Examination of eight failures of Textron Lycoming engines from a number of operators that had occurred over the period January 2000 to November 2001 revealed that deposits of lead oxybromide on combustion chamber surfaces were not restricted to the left engine of MZK on the accident flight; eight other engines had such deposits. The inclusion of a copper-based anti-galling compound between the bearing insert and big end housing was noted in three of the engines examined. The quantity of anti-galling compound present varied between those engines.

Lead oxybromide deposits and anti-galling compounds act in different ways to weaken the defences for reliable engine operation. The relative contribution to engine failure of

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the factors cannot be predicted easily because of variations in the extent of each effect and the complexity inherent in engine assembly and operation. It is likely that the formation of lead oxybromides that cause deposit induced preignition is linked to the temperature of the fuel-air charge temperature in the combustion chamber just prior to the passing of the flame front. Leaning the mixture during climb, and using near 'best economy' cruise power settings appeared to favour the formation of lead oxybromide deposits that resulted in deposit induced preignition. Mixture settings of 'full rich' mixture during climb and 'best power' cruise settings appeared to favour reactions that resulted in less extensive and different deposits being formed. The Whyalla Airlines procedure was to lean the mixture during climb, and to use a cruise power setting close to 'best economy'. Those procedures were in accordance with the US Federal Aviation Administration (FAA) approved Pilot's Operating Handbook for the Piper Chieftain aircraft.

The combination of the use of leaded aviation gasoline, mixture leaning during climb, and leaning for best economy during cruise was not restricted to Lycoming engines. The ATSB also found evidence of high combustion loads and lead oxybromide deposits during the examination of components from two Teledyne Continental TIO-520 engines that were defective.

Anecdotal reports indicated that there were fewer engine problems (including component failures) in engines that were operated full rich during climb, and 'best power' during cruise, compared with those where the mixture was leaned during climb and 'best economy' cruise power was used. A comparison of the engine operating procedures of twelve other operators of Piper Chieftain aircraft revealed considerable disparity in procedures, particularly for climb and cruise. In fact, no two operators used the same procedure.

The incidence of lead oxybromide deposits in engines that had experienced defects, coupled with the range of fuel leaning techniques used, indicated a deficiency in the operation and maintenance of those engines, at least among some of the operators of high-powered piston engine aircraft in Australia.

On 30 October 2000, the ATSB issued a recommendation that the Civil Aviation Safety Authority alert operators regarding the risks of detonation, and encourage the adoption of conservative fuel leaning practices.

This report includes further recommendations addressing the following:

- the engine operating conditions under which combustion chamber deposits that may cause preignition are formed (addressed to the US Federal Aviation Administration);
- the effect on engine reliability of the use of anti-galling compounds between connecting rod bearing inserts and housings (addressed to the US Federal Aviation Administration and the engine manufacturer); and
- the reliability of high-powered aircraft piston engines operated in Australia (addressed to CASA).

This accident was the first recorded ditching involving a Piper Chieftain aircraft in Australia. Available records world-wide of previous Piper Chieftain engine failure/ditching events illustrate that, in most instances, successful night ditchings occurred in better visibility and weather conditions than those confronting the pilot of

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MZK. The relatively minor injuries suffered by the occupants of the aircraft indicated that the pilot demonstrated a high level of skill in ditching the aircraft. The report includes a recommendation to CASA regarding guidance material for pilots on ditching.

It is likely that the survival prospects of the occupants would have been enhanced had the passenger seats been fitted with upper body restraints, and life jackets or equivalent flotation devices had been available to the occupants. As a result of a separate investigation, the Bureau issued a recommendation concerning upper body restraints on 31 March 1999. On 30 October 2000, arising from the Whyalla investigation, the ATSB issued recommendations to the Civil Aviation Safety Authority concerning the provision of adequate emergency and life saving equipment for the protection of fare-paying passengers in smaller aircraft during over-water flights.

Full details of safety action including the CASA response to recommendations made on 31 March 1999 and 30 October 2000 are in Section 4 of this report.

The investigation included a detailed examination of the regulatory history of Whyalla Airlines from June 1997 to June 2000. In common with the published findings of other reports on CASA surveillance activities, there was a significant under-achievement of surveillance of the company against CASA's planned levels during that period. However, there was insufficient information to conclude that the level of surveillance achieved was of significance with respect to the accident.

With regard to Whyalla Airlines itself, issues were identified in the company that had the potential to adversely influence safety. There was insufficient information to conclude that any of these issues were of significance with respect to the accident.

As a result of the accident and ATSB's investigation, improved refuelling procedures were introduced nationally by the refuelling organisation to reduce the chance of error.'

(Exhibit C97 p vii - x)

9.26. There are a number of differences between the draft and final versions of the ATSB report:

- The existence of a 'planar discontinuity' is not mentioned in the draft report;
- The existence of lead oxybromides, as distinct from lead oxides, is also raised for the first time in the final report;
- The analysis of the aircraft speed and propeller RPM information was obtained after the draft report was published;
- The draft report does not assert that there was a total engine failure at 1847:15. Indeed it suggests that both engines continued to deliver power throughout the cruise phase of the flight, and that the yaw to the right at 1847:15, and the reduction in groundspeed were consistent with a reduction in the power settings in the right engine (Exhibit C73d, p52). The final report rejects this thesis and states that the left engine failed totally at 1847:15.

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9.27. The assertion that leaning during climb, rather than in cruise, led to formation of these deposits, which in turn led to preignition, was also first raised in the final report.

9.28. When he gave oral evidence, the ATSB's Senior Transport Safety Investigator Mr Michael Cavenagh, outlined the process of logic which he applied to the investigation as follows:

- There is a very high probability against two independent engine failures occurring;
- There is no evidence to support the idea that the failure of the right engine had any influence on the failure of the left;
- Therefore, did the failure of the left engine influence the failure of the right;
- When Mr Mackiewicz made his radio call at 1856, he mentioned no problems, so he must have been satisfied that he had sufficient power to get to Whyalla on one engine;
- From 1856 to 1858 MZK descended at 400 feet per minute and if he had kept that up, MZK would have reached Whyalla at the nominated time;
- At 1858 the rate of descent increased to 650 feet per minute. At that rate the aircraft would not reach Whyalla;
- However, that rate of descent is consistent with one engine providing some power, otherwise it would have been 1000 feet per minute or a bit more;
- The fact that the wreckage analysis suggested that the right propeller was operating at impact with the water is consistent with the idea that the right engine was still functioning to some extent;
- The hole in the No.6 piston in the right engine would cause a substantial loss of power and 'surging' (T3527-3533).

9.29. Dr Arjen Romeyn, a Metallurgist and Transport Safety Investigator with the ATSB undertook the failure analysis on both engines of MZK. Dr Romeyn gave his analysis of the left engine failure as follows:

- The crankshaft in the left engine of MZK failed after only 262 hours service since factory overhaul as a result of fatigue crack propagation;

- The fatigue crack initiated below the surface of the journal and there was evidence of a planar discontinuity extending from the surface of the journal to the site of the initiation;
- There were cracks evident in nearby journals;
- The No.6 big end bearing housing had fractured;
- The bearings had been reduced to remnants of the steel backing;
- Other bearings showed signs of 'distress';
- The presence of approximately 50 'beach marks' suggested that the fatigue fracture occurred over a period in which the engine start/stop cycle took place 50 times;
- The plane of the crack was tilted 15° from the perpendicular to the crankarm and tended to spiral out into the journal, and the presence of the planar discontinuity, suggested that the section of the crankshaft journal which had been affected was the transition between the journal surface and the fillet radius, at a point where, if the connecting rod housing was able to move along the axis of the journal, it would contact that area causing localised heating;
- There was evidence that there had been movement between the bearing inserts and their housing within the big end of the connecting rod, caused by a lack of retention of the bearings. This could lead to longitudinal movement along the axis of the journal, forcing the bearing out into the small gap between the connecting rod housing and the crankshaft leading to the localised heating referred to above;
- The presence of small copper flakes suggested that an anti-galling compound had been used when the bearings were installed which potentially reduced the retention forces on the bearings which may have exacerbated their movement between the housing;
- The distress shown on the other bearings suggested that the loads from the combustion cycle of the engine were exceeding lubricant capacity of the engine at some stages during engine operation (T4020-4038).

9.30. As to the right engine failure in MZK, Dr Romeyn said that the significant features were:

- The edge of the No.6 piston melted to a point where the gas seal had been breached and combustion gases bypassed the piston and created a hole at the back of the piston rings;
- Other pistons showed some signs of edge deterioration which suggested that the piston crown temperatures were considerably above those normally expected;
- Residual oil in the sump was reported to be blackened in appearance and there had been some oil loss, although this was difficult to establish, and the engine had not been run to the point of seizure;
- The pistons in the right engine displayed a 'swirl pattern' which he considered to be unusual and inconsistent with what happened with another engine, in VH-NPA, where the failure occurred in the cruise phase of flight (T4065-4069).

9.31. I also heard evidence from Mr Kenneth Kell, a Senior Transport Safety Investigator with the ATSB who specialises in securing, analysing and interpreting recorded data from various sources.

9.32. Mr Kell told me that he calculated that MZK would have had a 20 knot tailwind during Flight 904, on the basis that MZK's groundspeed during Flight 903 was only 154 knots, and he would have expected the aircraft to fly at 174 knots during Flight 904 at 62% power. He used this information to calculate that the difference, 20 knots, was the headwind component for Flight 903 (T3755-6). This seems a rather arbitrary and unsatisfactory method of calculating a wind component.

9.33. He calculated that the average groundspeed of MZK between 1835 and 1847 was 177 knots (T3578).

9.34. A sophisticated audio analysis was performed by Mr Kell, in which the aircraft engine noise was analysed during very short time intervals, which could be detected during radio transmissions.

9.35. Mr Kell calculated that at 1823:12, while MZK was climbing through 500 feet, at least one of the engines was operating at 2,400 RPM, which is considered a standard setting for the climb phase of a flight (Exhibit C214a, p10).

9.36. At 1833:54, Mr Mackiewicz advised Melbourne Centre Air Traffic Control that he was maintaining 6,000 feet. The radar data indicates that MZK was flying at 183 knots at that point. Mr Kell's audio analysis disclosed that the propellers were revolving at 2,200 RPM during that transmission (Exhibit C214a, p11). This is also regarded as a standard setting for the cruise phase of a flight.

9.37. Mr Kell also calculated that at 1855:43, just before MZK reached the top of descent, the noise during a tiny gap in the transmission between Mr Mackiewicz and Melbourne Centre also disclosed that the engine was operating at 2,400 RPM (T3810). This was still in the cruise phase of the flight, so the engine should still have been operating at 2,200 RPM.

9.38. Mr Cavenagh argued that information from Piper Aircraft Corporation and Textron Lycoming indicated that if the left engine failed completely at 1847:15, the right engine was capable of providing sufficient power to maintain a true air speed of 147 knots (which is a groundspeed of 167 knots), as indicated by the radar data. In order to do so, however, it must have been operated 'outside normal limits', which could have induced detonation and damaged the right engine (T3534). (The material from Piper Aircraft Corporation and Textron Lycoming is attached to Exhibit C213).

9.39. However, Textron Lycoming in a commentary on the ATSB final report which is also part of Exhibit C213, said that in order to achieve sufficient horsepower to achieve that speed on one engine, the mixture would need to be leaned to a 'best power' setting (T3540). As I have already observed, this seems inconsistent with the metallurgical analysis which suggested that the carbonaceous deposits on the No.6 piston were consistent with the engine operating with a rich, not lean fuel/air mixture.

9.40. Mr Cavenagh argued that Mr Mackiewicz operated the right engine beyond its limits because the left engine failed first. He pointed to the variation and reduction in groundspeed indicated by the radar data between 1836 and 1847 (Exhibit C97, figure 53) and suggested that the left crankshaft completely fractured through by 1837:41. He argued that the two pieces of the crankshaft had remained 'dogged' or 'keyed' together until 1847:15 when the big end cap failed, and the pieces of crankshaft separated. This would have denied power to the oil pumps, fuel pumps etc, and the engine would have stopped then, and the propeller, the pitch of which was controlled by oil pressure, would have gone into 'feather' mode and ceased providing forward thrust.

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9.41. One difficulty with the ATSB theory is that at 1847:15 MZK diverged approximately 19° to the right. Nearly all the other pilots who gave evidence, including Mr Sargeant the retired ATSB investigator (T3679), said that the divergence to the right most strongly suggests that the right engine had failed or suffered a power reduction at that point, since an aircraft will yaw, or turn and bank, towards the failed engine until corrected with rudder (see the evidence of Mr Auld T3599, Mr Usher T1654, Mr Sharp T2405, Mr Thompson T3816, Mr K Brougham C73e, Associate Professor Taylor T3050, Mr Braly T3220-21).

9.42. Mr Cavenagh suggested that when the climb performance of the aircraft during Flight 904 was analysed, there was a high degree of consistency with the climb performance of MZK on its previous flight, and with the performance of another similar aircraft. From this, he concluded that it was 'very unlikely' that the right engine was undergoing detonation during the takeoff or climb phase of the flight (T3558), and that all the detonation damage occurred after 1847:15 as a result of the pilot 'overboosting' the right engine in response to the failure of the left engine (T3559).

9.43. Mr Cavenagh argued that Mr Mackiewicz's experience on 7 January 2000 when he was forced to land at Maitland after he lost the left engine was also significant. He said that the aircraft was unable to maintain altitude during that incident, and so Mr Mackiewicz may have firewalled the remaining engine on 31 May 2000 to avoid that happening again (T3543-3544).

9.44. Mr Cavenagh said that it would have been 'good airmanship' for Mr Mackiewicz to issue a 'Pan' call at 1847:15 when, on the ATSB contention, he lost the left engine. Other commentators used this as an argument against the engine having failed then (eg Mr Auld T3605, Mr Sargeant T3686 and Mr Sharp T2415). Mr Cavenagh said that Mr Mackiewicz probably thought he would still achieve Whyalla on one engine then, so he gave the usual advice that he was commencing descent at 1856 (T3528).

9.45. When I suggested that this was inconsistent with his argument that Mr Mackiewicz had, in the stress of the situation and remembering the problem he had in January 2000, overboosted the engine at 1847:15 to the extent that he burned a hole in the piston, Mr Cavenagh replied:

> 'I agree that there are inconsistencies there and the one thing about what humans do shouldn't surprise us, is that they surprise us with the way they react to different situations outside the normal zone that they operate in.' (T3562)

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He pointed to other cases where pilots had made wrong decisions in moments of stress (T3563).

9.46. I also heard evidence from Mr Roderick Fearon, another Senior Transport Investigator with the ATSB. Mr Fearon assisted Mr Cavenagh with the ATSB investigation after he took over from Mr Sargeant.

9.47. After Mr Cavenagh gave evidence-in-chief, he became unwell and was unable to attend court to be cross-examined for the foreseeable future. Mr Fearon was made available by the ATSB to answer as many questions as he could arising from Mr Cavenagh's evidence.

9.48. Single Engine Performance

Mr Fearon produced material from the Bureau of Meteorology (Exhibit C220a) which states:

> 'Our estimate of the wind at 6000 feet near Alford in the early evening of 31 May is from 170 to 150 degrees true at a speed of between 15 and 20 knots.' (Exhibit C220a, p3)

Alford is in the general area where MZK was flying that evening.

9.49. Mr Fearon also referred to material provided from Textron Lycoming, and from Piper Aircraft Corporation, part of Exhibit C213. He expressed the opinion, that using a tailwind of 20 knots, MZK was capable of flying on one engine, with the failed engine propeller feathered, at a true airspeed of 147 knots. He was less certain that it was capable of achieving a true airspeed of 152 knots, which would be necessary using a tailwind component of 15 knots (T4347). He argued that Mr Braly's test in America supports this contention, even allowing for the fact that Mr Braly's aircraft was 350 pounds lighter, and that it was equipped with winglets (T4350). I will refer to Mr Braly's analysis of this issue in Section 12 (paragraphs12.95-96).

9.50. Mr Fearon acknowledged that if the density controller on the turbocharger was correctly adjusted, the engine on MZK should not have been producing more than 350 horsepower, whereas he was required to acknowledge that in order to achieve 147 knots TAS, the engine must have been able to produce more than 370 horsepower at 2,400 RPM between 1847:15 and 1855:54 (T4370).

9.51. The difficulty I have with Mr Fearon's evidence on this topic is that he is happy to seize upon data, such as that produced by Mr Braly, as supporting his theory, but when contradictory data was put to him, he reverted to rather facile positions.

9.52. For example, I put to Mr Fearon that it was all very well referring to an average groundspeed of 167 knots, as calculated by Mr Kell from the radar data, but a reference to that same data suggests that the groundspeed varied up and down by a factor of five to six knots (T4371). If one accepts that the groundspeed dropped as low as 163 knots on occasion, one must also accept that it increased to 173 knots on other occasions in order to maintain the average of 167 knots. In order to achieve those peaks of 173 knots, and allowing for a tailwind component of 20 knots, this would have required the aircraft to achieve a true airspeed of 153 knots, and allowing for a 15 knot tailwind component, this would have required a true airspeed of 158 knots. Mr Fearon's response was that the radar data has its limitations (see the discussion at T4370-73).

9.53. Indeed, Mr Fearon acknowledged that if the density controller on the turbocharger was effectively limiting the power output to 350 horsepower, then the documentation from Piper Aircraft Corporation and Textron Lycoming does not support the assertion that the aircraft could obtain 147 knots true airspeed, let alone 153 knots or 158 knots (see the discussion at T4523).

9.54. Mr Fearon was happy to use Mr Braly's findings, but when it became clear that the demonstration conducted by Mr Braly in America, which was demonstrated by him in a CD rom video (Exhibit C196m), was in an aircraft which, as I have already mentioned, was 350 pounds lighter, was fitted with winglets which reduced the drag of the aircraft, and was fitted with an intercooler, (which will allow the engine to produce more horsepower than a non-intercooled engine for the same manifold pressure) (T4524). Mr Fearon was unable to suggest what the difference in performance would have been having regard to these variations in specification of the aircraft (T4526-27).

9.55. Beyond that discussion, Mr Fearon's evidence became unhelpfully speculative. For example, it was his suggestion that the pilot, Mr Mackiewicz may well have pushed the right engine up to a full power setting after the left engine failed, because it was his experience from the Maitland incident that the aircraft could not maintain altitude on one engine (T4547). However, in the Maitland incident there was extensive damage to the engine cowling which created significant drag, to the extent that the aircraft was unable to maintain altitude. See the photographs which appear at page 99**.** In this case there was no such damage to the cowling, yet Mr Fearon argued that Mr Mackiewicz might have jumped to the conclusion that MZK might behave in the same way in the absence of any decrease in the engine performance (T4548).

9.56. By the time Mr Fearon was being cross-examined by Mr Eriksen, the inconsistency between the allegation that Mr Mackiewicz had 'firewalled' the throttle on MZK without making a corresponding adjustment to the fuel mixture, thereby creating an unduly lean fuel/air mixture, on the one hand, and the evidence of Dr Romeyn that the carbonaceous deposits on the No.6 piston from the right engine indicated that it had been operated at a rich mixture setting, on the other, had become apparent.

9.57. Mr Fearon said that it was a possibility that Mr Mackiewicz did make the appropriate adjustment to the mixture, pushing it to full rich, but neglected to open the cowl flap, thereby allowing the engine cylinder head temperature to increase (T4549). It seems difficult to accept that failure to open the cowl flap would have been responsible for the engine overheating to the extent that aluminium would melt. It would seem extraordinary that Mr Mackiewicz would not notice a significant increase in cylinder head temperature if this had occurred. Mr Fearon's theory also overlooks the fact that the cowl flaps were open when the aircraft hit the water, on the evidence of the wreckage examined after it was recovered (see Exhibit C97).

9.58. Mr Fearon pointed out that even the most highly trained professional pilots can make mistakes in piloting an aircraft, sometimes with tragic results. He cited several examples at T4560. I accept this evidence as far as it goes. However, these errors were made on the spur of the moment, whereas the error alleged by the ATSB to have been made by Mr Mackiewicz extended for eight minutes or more.

9.59. Recommendations

The final ATSB report made the following recommendations:

R20010254 – The Australian Transport Safety Bureau recommends that the Federal Aviation Administration (Piston Engine Certification Directorate) review the certification requirements of piston engines with respect to the operating conditions under which combustion chamber deposits that may cause preignition are formed.

R20010255 – The Australian Transport Safety Bureau recommends that the Federal Aviation Administration FAA (Piston Engine Certification Directorate) review the practice during assembly of applying anti-galling compounds to the backs of connecting rod bearing inserts with respect to its affect on the safety margin for engine operation of the bearing insert retention forces achieved.

R20010256 – The Australian Transport Safety Bureau recommends that Textron Lycoming review the practice during assembly of applying anti-galling compounds to the backs of connecting rod bearing inserts with respect to its affect on the safety margin for engine operation of the bearing insert retention forces achieved during assembly.

R20010257 – The Australian Transport Safety Bureau recommends that the Civil Aviation Safety Authority review the operating and maintenance procedures for high-powered piston engines fitted to Australian registered aircraft to ensure adequate management and control of combustion chamber deposits, preignition and detonation.

R20010258 – The Australian Transport Safety Bureau recommends that the Civil Aviation Safety Authority educate industry on procedures and techniques that may maximise the chances of survival of a ditching event. Part of that education program should include the development of formal guidance material of the type contained in the UK CAA General Aviation Safety Senses leaflet 21A Ditching. (Exhibit C97, p121 - 123)

9.60. Issues, Discussion and Conclusions – see Section 14

Further discussion of the issues arising from this section, and the conclusions to be drawn from them, appears in Section 14 of these findings.

(Signed)

10. Events in the Aircraft Industry 2000 - 2002

10.1. On 14 April 2000 Teledyne Continental Motors (TCM), who make aircraft engines similar to those made by Textron Lycoming, issued a Mandatory Service Bulletin (MSB). The explanation for the MSB is as follows:

> 'BACKGROUND: Teledyne Continental Motors (TCM) has identified the cause of 11 crankshaft fractures which have occurred in the connecting rod journals on straight drive engines manufactured in 1998 and 1999. The cause of the fractures has been identified as composition and processing deficiencies during several discrete periods of steel production and/or forming operations by suppliers. The fractures have occurred in new, rebuilt and field overhauled engines with operational times varying from 15 to 1257 hours. TCM is working closely with its suppliers to insure future production integrity.'
>
> (Exhibit C222c, LL-H)

10.2. Seven engines in Australia were affected by the MSB. The MSB required that core samples be taken from affected crankshafts within the next 10 hours of operation. The MSB carried the following warning:

> 'The inspection required by this service bulletin is intended to detect metallurgical anomalies which if present and left uncorrected can result in engine failure.'
>
> (Exhibit C222c, LL-H)

10.3. On 18 April 2000, Mr Ken Howard, Regional Manager for TCM, telephoned Mr Les Lyons, who is the Technical Specialist - Powerplants in the Airworthiness Branch of CASA, and advised him of TCM's concerns for crankshafts manufactured at the Green River Foundry in the United States of America (T4405).

10.4. Later that day, Mr Lyons telephoned Mr Adrian McHardy, the Regional Manager for Textron Lycoming and asked him whether Lycoming engines were affected by the anomaly. Mr McHardy assured him that the crankshafts manufactured by Textron Lycoming were sourced from a different foundry and were not affected (T4406).

10.5. On 20 April 2000, CASA issued an Airworthiness Directive (AD) putting into effect the MSD from TCM. The AD was effective from 26 April 2000 (Exhibit C222c, LL-I).

10.6. On 28 April 2000, the United States' Federal Aviation Administration (FAA) issued an Emergency AD also mandating the MSB issued by TCM. The Emergency AD, after noting advice of 11 crankshaft failures, included the statements:

> 'The investigation revealed that the crankshafts failed due to subsurface defects in the number one crankshaft connecting rod journal. The FAA has determined that all of the defects were due to unique material composition characteristics combined with process control variations that occurred during the material melt process. This occurred during several discrete periods, i.e. certain lots, of steel production or forming operations. Specification material evaluation techniques were inadequate to detect these anomalies, and therefore the defects were not revealed during manufacture. The specification material evaluation techniques have been improved to preclude a reoccurrence of this condition. Crankshafts with this type of subsurface defect will always result in failure.' (Exhibit C222c, LL-J)

10.7. On 11 July 2000, Mr McHardy visited Canberra to provide 'support' for the ATSB investigation into this incident. Mr Lyons, who attended a meeting with participants in the investigation on that day, recorded that Mr McHardy was told that since the left crankshaft in MZK had only been in service for 262 hours before it failed, 'the airworthiness of other crankshafts released by Lycoming of the same batch or subcontract manufacturer is of significant concern' (Exhibit C222b, LL-5).

10.8. Textron Lycoming had sought approval from the ATSB for their Senior Metallurgist, Dr Yoon Kim, to participate in the metallurgical analysis of the failed crankshaft from MZK. This was granted, but the examination was delayed because the ATSB metallurgist, Dr Arjen Romeyn, had a fractured ankle and was only available part-time. The delay caused Mr Lyons significant concern (T4424-25).

10.9. During the same meeting on 11 July 2000, Mr McHardy expressed the opinion that the 'torched' No.6 cylinder in the right engine of MZK was due to detonation of the fuel/air mixture within the cylinder due to a spark plug having been dropped, and the porcelain insulator cracked, before installation. Mr McHardy pointed out that this had caused a failed cylinder on a previous occasion in an aircraft owned by Whyalla Airlines (VH-NPB) in August 1999. I will discuss this incident later in these findings.

10.10. Surprisingly, the spark plugs were not tested by the ATSB to examine Mr McHardy's theory.

10.11. On 13 July 2000, Textron Lycoming issued an MSB recommending that oil and oil filters be changed and screens cleared within 10 hours of operation, and at 25 hour intervals thereafter (Exhibit C222c, LL-E). Mr Lyons said that he had been informed that Textron Lycoming had been concerned for several years about evidence of bearing failures. In July 1999 they had commenced a program to replace aluminium-clad bearings with copper cast bearings, and TCM had done the same (Exhibit C222a page 6). It was Textron Lycoming's view that any problems with bearing delamination would be picked up by such inspections (any small metal fragments given off during bearing failure would be collected in the oil filters - Exhibit C222a page 6).

10.12. On 31 August 2000, Textron Lycoming issued a Special Advisory Bulletin concerning bearing failures in Textron Lycoming engines of a different type to the one in MZK. The bulletin states:

> 'Two instances of connecting rod bearing failures have occurred recently on relatively low time TIO-540-AE2A engines. The failure results in a disintegration of the bearing most likely due to delamination of the bearing surface. Lycoming has found no apparent operational or dimensional cause for these two occurrences; however, in an effort to minimize any chance of an additional occurrence, Lycoming will be instituting a mandatory replacement program to equip the subject engines with connecting rod bearings with increased durability. The program will be initiated on October 2, 2000.' (Exhibit C222c, LL-K)

10.13. On 29 September 2000, Mr Lyons emailed Textron Lycoming advising them of the findings of the investigation to date. He advised them of the opinion that the left crankshaft fatigue crack initiated from a 'thermal strain crack' due to failure of the big end bearing. He sought advice on whether Textron Lycoming had experienced similar failures in the past two years or so and if so, whether the cause of both the crankshaft failure and the bearing failure had been identified. Mr Lyons has never received a reply (Exhibit C222b, LL-4).

10.14. On 29 September 2000, Mr Lyons emailed the FAA, seeking similar information. He did not receive a response from the FAA until 23 February 2001 and this reply did not address the issues he had raised (Exhibit C222b, LL-7). This does not represent a good example of the much-vaunted international cooperation which is supposed to be a feature of aviation regulation based upon the Chicago Convention on International Civil Aviation.

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10.15. First acknowledgement of crankshaft problems with Textron Lycoming engines

On 9 November 2000, Textron Lycoming issued a Special Advisory Bulletin (SAB) addressed to their customers who were known to have engines with particular serial numbers. The letter stated:

> 'Textron Lycoming has identified a metallurgical problem on a small number of crankshafts in our facility. Our records indicate that your engine was assembled with a crankshaft from the suspect lot. Due to the nature of the possible problem, the affected engines/crankshafts must be inspected within next 10 hours of operation.'
>
> (Exhibit C219c)

The letter then went on to outline a testing procedure which could be performed without removing the engine from the aircraft.

10.16. Textron Lycoming did not specify the nature of the 'metallurgical problem' referred to.

10.17. On 28 November 2000, Mr McHardy telephoned Mr Lyons and told him about the SAB. He told Mr Lyons that 'no Australian operators were affected'. Mr Lyons said that this was 'the first document received by CASA which referred to a material problem or anomaly in Lycoming crankshafts' (Exhibit C222a, p6).

10.18. On 21 December 2001, Mr Richard Moffett of Textron Lycoming emailed Mr Lyons providing him with a brief summary of the ongoing investigation Textron Lycoming was undertaking in relation to broken crankshafts. The update was as follows:

> 'Recently, Textron Lycoming became aware of a trend of broken crankshafts in turbocharged-540 engines over 310 horsepower. Several factors related to these instances have prevented a valid conclusion that the occurrences result from a single cause.
>
> 1. Some of these engines displayed evidence of possible contributing factors such as high combustion temperature or detonation that would promote abnormal crankshaft loading.
> 2. Some engines sustained movement of the rear main bearing that may have been either a cause or effect of the broken shaft.
> 3. Textron Lycoming has been unable to completely examine certain engines which has impeded drawing conclusions in those cases.
>
> The investigation conducted to date has indicated no dimensional discrepancies as causal factors. Metallurgical examination of the crankshafts has revealed no discrepancies to the specification properties. Lycoming has monitored the crankshaft recall affecting Teledyne Continental Motors engines and is evaluating whether this problem or

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something similar, could be a factor in some of the broken crankshafts. A summary of the problem experienced by TCM seems to be pre-existing grain boundaries within the material that fail to breakdown as the grain structure size is intentionally reduced during the manufacturing process. These features have a honeycomb appearance dispersed through the material matrix. There are some similarities with the TCM issue in that Lycoming has identified honeycomb-like features in some of the broken crankshafts. However, there are some significant differences in the chemical composition of the steel material and producing sources between TCM and Lycoming. Also, Lycoming has not been able to identify the honeycomb feature at the origin of any of the cracks. We are currently in the investigation process involving both internal metallurgical capabilities as well as a number of outside laboratories.' (Exhibit C222b, LL-4)

10.19. Mr Lyons replied on 25 December 2001 that he had been made aware of a number of crankshaft bearing failures in Australia, and had been told of a set of replacement bearings from a German manufacturer with cracks in them. He was investigating that matter further.

10.20. On 27 December 2001, Mr McHardy telephoned Mr Lyons advising him of an impending recall of certain batches of Textron Lycoming crankshafts. He told Mr Lyons that there were seven engines in Australia that had crankshafts from those batches (Exhibit C222a, p6).

10.21. On 1 February 2002, Textron Lycoming issued a MSB No. 550. The MSB states:

'Lycoming has received several field reports of broken crankshafts in six-cylinder turbocharged engines. Lycoming believes the problem is related to the material used in these crankshafts. The engines assembled with the suspect crankshaft are listed in Table 1….Due to the nature of the problem, there is no field process currently available to identify crankshafts potentially affected. Therefore, Lycoming requires that all the engines listed below be returned to the factory for crankshaft replacement within 10 hours of operation.' (Exhibit C222c, LL-O)

The MSB then lists approximately 400 engine numbers including the number of one of the engines in VH-NPB, another of Whyalla Airlines' Piper Chieftains. The significance of this is clear from the statement of Mr Karl Jelinek. Mr Jelinek referred to the incident on 7 January 2000 when Mr Mackiewicz lost an engine and was forced to land at Maitland, South Australia and said:

'The engine failure on VH-MZK which occurred at Maitland was as a result of the failure of a con-rod little end. This allowed the con-rod to swing freely, allowing the end of the con-rod to hit the cylinder base and dislodged it from the crankcase. At the time of this failure Whyalla Airline had purchased 2 Textron Lycoming Factory overhauled engines for VH-NPB which was becoming due for a double engine change.

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One of these engines was fitted to VH-MZK at Maitland in January 2000. It was this left-hand engine, which was subsequently found to have a broken crankshaft after the accident on the 31st May 2000.

The second factory overhauled engine was fitted to VH-NPB in about February 2000. This engine was subject to recall as a result of the Mandatory Service Bulletin No. 550, issued by Textron Lycoming, dated the 1st February, 2002. The basis of the recall was a result of several reports of broken crankshafts in six-cylinder turbocharged engines. A list of Model and engine serial numbers was included in the Service Bulletin. The serial number of the engine fitted to VH-NBP (NPB) appears on this list and therefore was subject to the recall. This recall list is included at Appendix A. The serial number of the engine fitted to VH-MZK did not appear on the list, I have been told this was due to the fact that it had already failed.' (Exhibit C147d, p2-3)

10.22. Mr Lyons emailed Mr Moffett at Textron Lycoming on 3 February 2002 in relation to MSB 550, expressing concern about other Textron Lycoming engines, not mentioned in MSB 550, which had been fitted with new crankshafts since September 1999. He requested further information about the precise nature of the 'material problem' referred to. This was not answered by Textron Lycoming directly, they simply reiterated that MZK's failure was secondary to a failed connecting rod bearing (Exhibit C222b, LL-4).

10.23. In February 2002, Mr Lyons received a copy of a 'briefing' from the FAA. The paper is dated 5 February 2002 (Exhibit C222b, LL-4). Mr Lyons forwarded this paper to the ATSB for their information. The paper states 'between March 21, 2000 and January 25, 2002 there have been 15 failures of crankshafts, 14 in TIO-540 engines and 1 in an IO-540'. The paper records:

'The facts are

- The 15 crankshaft failures are very similar and can be classified into 7 confirmed failures (parts analyzed by T/L) and 8 unconfirmed failures (parts not analyzed or being analyzed by T/L).
- No injuries have occurred in the confirmed failures and only one failure is classified as an accident.
- 8 fatalities are reported in one of the unconfirmed failures. This failure occurred in Australia and the Australian National Safety Board (sic) has attributed this failure to engine detonation due the engine leaning procedure used by several Australian operators.
- All crankshafts failed in the rear crossover cheek (cheek #8) and originated in either the rear radius of the #5 crankpin (1 failure) or the front radius of the #6 crankpin (14 failures).

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- All the failed crankshafts were manufactured from material with a modified vanadium content. T/L released the vanadium modified specification on January 15, 1999 to minimize the need for straightening the crankshaft later in the production cycle. Currently, the increased vanadium content, increase in trace elements and changes in the heat treats are the only changes known in the manufacturing process. The time period between March 1, 1999 and December 31, 1999, is defined as the "suspect time period" because the heat codes that failed were produced in this period.
- 420 TIO-540 engines and 344 IO-540 engines were produced in the "suspect time period". The 420 TIO-540 engines can be divided into two groups:
- 232 engines in heat codes that had crankshaft failures, and
- 188 engines in heat codes that did not have crankshaft failures.
- The 7 failed crankshafts that were analyzed contained a "honeycomb feature" in approx. 0.05% of the total fracture area that was not present in crankshafts manufactured before the addition of vanadium. However, ANM-112N is not convinced that the inclusion of vandium alone is detrimental or that the "honeycomb feature" is causing the failures.
- Additional information also showed that vanadium in amounts equal to the modified specification were present in some of the material produce in 1997 with no known failures.
- All failed crankshafts were made from the same forging part number.
- All failed crankshafts were made from material obtained from Republic Steel. It should be noted that a specimen from Universal Steel (another T/L approved supplier) that was made to the modified AMS 6414 specification also contained a "honeycomb feature".
- Failures have occurred in six models of the TIO-540 engine and one model of the IO-540
- Total engine times to failure range from 100 hours to 1040 hours
- Horsepower ratings of the failed engines range from 300 to 350 HP
- There are other TIO/IO-540 engine models with the same HP and RPM ratings that have not failed but, it is currently now known how many, or if any, of these models were produced in the "suspect time period".
- Production of the IO/TIO-540 engines is continuing based on the fact that these crankshafts were not produced in the "suspect time period" and the steel is from a different mill.' (Exhibit C222b - document LL-4) (my underlining)

10.24. The paper outlined that on 22 and 23 January 2002, Textron Lycoming were visited by a team from the FAA and advised that they were still trying to identify the problem and to determine a method of testing for the problem. It is to be noted that the FAA and Textron Lycoming had taken on board the ATSB conclusion that the Australian failure was caused by engine detonation due to leaning procedures, rather than by a defect in the crankshaft itself (see underlined sentence in the passage quoted above).

10.25. Also on 5 February 2002, Textron Lycoming supplied a list of the seven confirmed crankshaft failure incidents to CASA (Exhibit C222b, LL-4). Of those, it would appear that none occurred prior to 31 May 2000 when MZK crashed, although details as to the failure dates were not supplied.

10.26. On 11 February 2002, the FAA issued an Emergency AD which gave mandatory effect to MSB 550 in the United States. This referred to 14 crankshaft failures, not 15, having occurred (Exhibit C222c, LL-P).

10.27. On 13 February 2002, CASA issued an Airworthiness Directive (AD) which gave mandatory effect to MSB 550 in Australia (Exhibit C222c, LL-Q).

10.28. On 16 August 2002, after this inquest had commenced, Textron Lycoming issued another MSB, No. 552, which 'supersedes and replaces Service Bulletin No. 550'. The 'Time of Compliance' section is expressed in even more urgent terms: 'Before further flight'. That MSB recalled a much larger number of engines (Exhibit C222c, LL-T).

10.29. Also on 16 August 2002, the FAA issued another Emergency AD, this time referring to 17 crankshaft failures (Exhibit C222c, LL-S). This AD mandated MSB No. 552 issued by Textron Lycoming the same day, and also required removal of the crankshaft 'before further flight'.

10.30. On 19 August 2002, CASA issued an AD which mandated MSB No. 552 in Australia (Exhibit C222c, document LL-U). CASA allowed compliance within five hours time in service from 21 August 2002.

10.31. On 16 September 2002, Textron Lycoming issued a further MSB No. 553. It states:

> 'Lycoming has received a field report of a broken crankshaft in a six-cylinder turbocharged engine. The report affected a product outside the range recalled by Service Bulletin No. 552. Metallurgical testing indicates that the cause is material related. Lycoming requires that affected crankshafts be inspected. During the inspection, three core samples will be removed from the crankshaft propeller flange by a Lycoming authorized representative.' (Exhibit C222c, LL-V)

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The MSB stipulates that the inspection need only be carried out within the next 50 hours time in service, or six months, whichever occurs first. Included in the list of about 3,000 engines and crankshafts attached to the MSB, on page 10, is crankshaft serial number V537912936, the crankshaft in the left engine of MZK.

10.32. On 20 September 2002, the FAA mandated MSB No. 553 (Exhibit C222c, document LL-W) for the United States.

10.33. On 26 September 2002, CASA mandated, with some variations, MSB No. 553 for Australia (Exhibit C222c, LL-Y).

10.34. <u>Issues, Discussion and Conclusions</u>

10.35. *Was there any information available prior to 31 May 2000 which gave notice of potential defects in Textron Lycoming TIO-540 engines? If so, were the engine failures in MZK avoidable?*

10.36. There was concern about fractured crankshafts in aircraft engines prior to 31 May 2000, but that concern related to crankshafts in Teledyne Continental Motors (TCM) engines in relation to which a Mandatory Service Bulletin was issued on 14 April 2000. The cause of these fractures had been identified as 'composition and processing deficiencies' during steel production. The Regional Manager for Textron Lycoming assured Mr Les Lyons of CASA on 18 April 2000 that the crankshafts manufactured by Textron Lycoming were not affected by these concerns. I accept that there was no notice, particularly as far as the Australian authorities were concerned, that there was any difficulty in relation to the crankshafts in Textron Lycoming engines.

10.37. *Is the flow of information and technical expertise between regulatory agencies, aircraft manufacturers, engine manufacturers and others adequate to prevent similar failures in the future?*

10.38. The evidence of Mr Lyons that Textron Lycoming and the US Federal Aviation Administration had failed to respond to concerns elicited by CASA in Australia, and the dearth of information received by the ATSB in the course of their investigation into the fractured crankshaft in MZK, clearly suggests that the flow of information and technical expertise between regulatory agencies, aircraft manufacturers, engine manufacturers and others is completely inadequate to prevent similar failures in

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future. The ATSB has not received any detailed information about the cause of crankshaft failures in the United States with which to compare the fractured crankshaft in the left engine in MZK, and with the fractured crankshaft in VH-JCH, the Sharp Aviation aircraft.

10.39. *Do the various recalls by Textron Lycoming, and the various notices and bulletins issued both in the US and in Australia since 31 May 2000 provide evidence which is useful in determining whether the crankshaft in the left engine of MZK was faulty?*

10.40. The Mandatory Service Bulletin (MSB) No. 553 issued by Textron Lycoming on 16 September 2002 includes the crankshaft serial number V537912936, the crankshaft in the left engine in MZK, as one of about 3,000 crankshafts which are said to be affected by the MSB which states 'metallurgical testing indicates that the cause is material related'.

10.41. This MSB was the culmination of various SAB's and MSB's since November 2000 which had referred to 'metallurgical problems on a small number of crankshafts', 'honeycomb-like features', 'related to the material used in these crankshafts', and 'the cause is material related'.

10.42. In addition, a 'briefing paper' issued by the FAA in February 2002 referred to other common features in the 15 established failures at that stage, all of which were described as 'very similar':

- the fractures all occurred in the vicinity of the No.6 journal (crankpin) radius;
- all of the failed crankshafts had a modified vanadium content;
- all were produced in the same 'suspect time period';
- all seven of the crankshafts which had been examined had a 'honeycomb feature';
- all failed crankshafts were made from the same forging part;
- all failed crankshafts were made from materials supplied by Republic Steel;
- all of the failed engines had horsepower ratings from 300-350 horsepower.

10.43. The combined effect of all this information strongly suggests that the failed crankshaft in the left engine of MZK was faulty for the same reasons as are outlined in the FAA briefing paper.

10.44. *If a faulty crankshaft was the cause of the failure of the left engine of MZK, did the ATSB investigation mislead US Authorities into concluding otherwise? If so, did that detract from aviation safety in general?*

10.45. It is clear that the ATSB conclusion that the failure of the left engine crankshaft in MZK on 31 May 2000 was initiated by thermal cracking as a result of bearing failure, rather than from a material defect in the crankshaft, affected the investigation in the USA. As a result, the MZK failure was put in the unconfirmed category. The briefing in February 2002 by the FAA states:

> '8 fatalities are reported in one of the unconfirmed failures. This failure occurred in Australia and the Australian National Safety Board (sic) has attributed this failure to engine detonation due to the engine leaning procedure used by several Australian operators.'
>
> (Exhibit C219d)

To that extent, the ATSB conclusion led the US Authorities to believe that the failure of the left engine crankshaft in MZK on 31 May 2000 was not relevant to their investigations, despite the highly suggestive circumstantial evidence outlined above.

11. Related incidents

11.1. It is instructive to examine a number of other incidents which occurred both at Whyalla Airlines and at other companies involving Piper Chieftain aircraft. Some of these incidents occurred before 31 May 2000 and others since that date.

11.2. <u>June 1999</u>

On 4 and 11 June 1999, two incidents involving the Piper Chieftain VH-XMC occurred which may illustrate the way Whyalla Airlines and the Chief Pilot Mr Kym Brougham dealt with safety issues.

11.3. On 4 June 1999, XMC's pilot was Mr Samuel Hill, a friend and colleague of Mr Mackiewicz. A light which should have indicated that the undercarriage was down and locked in, an essential ingredient of a safe landing, was faulty. Mr Hill flew past the Adelaide control tower several times so that the flight controllers could examine the undercarriage and advise Mr Hill on the radio that it was down and that it was safe to land.

11.4. Mr Brougham said that the light was repaired after this incident (T2534).

11.5. On 11 June 1999 the same thing happened, and this time Mr Mackiewicz was the pilot. A passenger complained to Mr Brougham about the event (he had been on the flight when the same thing had happened the week before), and about the fact that the passengers were not briefed about what was happening. Mr Hill said that this was because the rear speaker in the aircraft was not working (Exhibit C173c, page 5).

11.6. As a result of this incident, Mr Brougham 'gave notice' to Mr Mackiewicz. Mr Brougham said that Mr Mackiewicz was removed from RPT (regular passenger transport) flights, and put on charter and ferry flights. He was advised to seek employment elsewhere. He continued to fly with Whyalla Airlines, however, and resumed RPT flights later in the year.

11.7. Mr Brougham gave a rather convoluted explanation for these events. He brought in another issue, the amount of fuel remaining at the end of the flight. He said:

> 'I spoke by telephone to a passenger who was on the same flight exactly the week previously. He described the difference about how the pilots had handled the matter.
>
> Although the initial focus was the concerns of that passenger, it soon became apparent to me that other issues were involved.

> Ben could not satisfactorily describe to me that part of the flight from when he first observed an incorrect undercarriage indication until after landing.
>
> He did not seem to recall the flight path, where radar had vectored the aircraft, the power settings used, and whether the undercarriage was left extended or not.
>
> I became concerned that it was possible that he was under stress, and that that stress may have affected his ability to remain in control of the aircraft.
>
> This was not the most serious emergency. I became concerned about whether Ben would handle a more serious emergency.
>
> My attention was now drawn to and focused on how Ben would cope in an emergency. Ben's attitude on this issue was one of complete indifference. This indifference was an issue of further concern to me. I saw such an attitude of indifference impeding any revision training that I chose to undertake.' (Exhibit C73f, p12)

11.8. Mr Brougham said that he decided later that Mr Mackiewicz's 'attitude had changed', so he allowed him to resume his duties (Exhibit C73f, p12).

11.9. I have great doubts about the veracity of Mr Brougham's explanation. The evidence of Mr Malcolm Sharp, the Managing Director of Sharp Aviation, who was something of a mentor to Mr Mackiewicz, and whom Mr Mackiewicz telephoned after the incident to seek his advice, was that far from being indifferent, Mr Mackiewicz was very concerned about what happened (T2400-2401). Another pilot, Mr Tim Kuch, also said that Mr Mackiewicz was 'upset' about the incident (T1440).

11.10. I am of the opinion that Mr Brougham's explanation for his behaviour was reconstructed to avoid the admission that he acted unreasonably over this incident. The failures of the light and loudspeaker were his responsibility, not Mr Mackiewicz's. I think that Mr Brougham was inclined to blame Mr Mackiewicz at the time for what happened out of frustration and embarrassment arising out of the passenger's complaint.

11.11. The only reason this incident is significant is that it gives rise to the suggestion, which must be examined, that Mr Mackiewicz may have been disinclined to report adverse events following this incident because of Mr Brougham's perfectionist and hyper-critical attitude.

11.12. <u>9 September 1999</u>

On this day another Piper Chieftain, VH-BYG was on a trip from Whyalla to Adelaide when the pilot noticed vibration in the left engine. The engine did not fail, and the aircraft completed its journey to Adelaide. When it was examined by Rossair

Pty Ltd in Adelaide, one of the cylinders was found to have suffered 'unusual erosion damage' in the words of Mr Brougham (Exhibit C73e, Attachment 3). A new set of cylinder assemblies had only been fitted to BYG the previous month.

11.13. Mr Brougham said that the Regional Manager for Textron Lycoming, Mr Adrian McHardy, told him that a cracked spark plug had caused 'torching' of the cylinder, but he was more inclined to believe that the cylinder was damaged by end gas detonation in the engine.

11.14. Significantly, Mr Brougham said that the vibration and, inferentially, the damage occurred during the climb, or at the end of climb and beginning of cruise phases of the flight (T2715). This is the phase, identified by Mr Braly and others, when MZK may also have suffered damage.

11.15. <u>7 January 2000</u>

On this day Mr Mackiewicz was the pilot of MZK. He was flying from Cleve to Adelaide when at about 5:35pm the left engine suffered a 'catastrophic failure' when the entire front cylinder separated from the engine, along with a section of the crankcase to which it was attached. It was later determined that a failure of the connecting rod to the No.1 piston had failed at the small (piston) end, which in the words of CASA, was attributed to 'maintenance error' (CASA Submissions, p6). I have no evidence before me to verify this conclusion. The issue was not examined in detail since the mechanism of the breakdown was completely different from what occurred on 31 May 2000. The separation of the cylinder and part of the crankcase caused severe damage to the engine cowling, which would have created significant drag and made it difficult to maintain height. Reproduced below are pictures taken of the aircraft after the incident (Exhibit C170f):

(Signed)

11.16. The Air Services incident report is as follows:

> 'At approx 50 miles on the Cleeve (sic) – Adelaide track, the pilot of MZK declared a Pan for an engine failure. Initially the pilot indicated that he could maintain altitude and continue to Adelaide. Following coordination with approach the pilot changed his mind and indicated that he couldn't maintain altitude and wished to divert to Maitland aerodrome which was approximately 5nm west. Ardrossan aerodrome was also in close proximity. Following further questioning the pilot indicated nine persons on board and full emergency services were required. The pilot was left alone to complete his landing. At 0707, five minutes after the initial emergency declaration the aircraft landed safely at Maitland and advised that emergency services were no longer required.' (Exhibit C98b)

11.17. It was alleged that Mr Brougham was critical of Mr Mackiewicz for landing at Maitland, rather than flying on to Adelaide, over Gulf St Vincent, on one engine (see evidence of Mr Kuch T1442 and Mr Usher T1685).

11.18. Mr Kuch said that he spoke to a number of the passengers who were on that flight, and their reactions are in contrast to Mr Brougham's alleged concerns about Mr Mackiewicz's ability to handle stressful situations:

> 'Yes, the passengers I had spoken to that I had previously flown with myself all praised his actions and he kept his cool, was cool, calm and collected through the procedure and did it confidently.' (Kuch T1442)

11.19. Mr Brougham denied that he was critical of Mr Mackiewicz. He alleged that there was little discussion of the incident on the day (Exhibit C73f, p11). Mr Brougham was quoted in the press as saying:

> 'Mr Brougham said the passengers had not been endangered, as the plane was capable of carrying on to Adelaide in its damaged condition, but the pilot had judged it prudent to land at Maitland, where a sealed strip was close at hand.' (Exhibit C170f)

11.20. Mr Brougham said this was intended to alleviate the concerns of the flying public, and not as an implied criticism of Mr Mackiewicz. He acknowledged that the damage to the engine cowling was extensive and would have created significant drag to the extent that to continue over water would create 'significant risk' to the passengers, and that 'the decision to land was a better preferable alternative' (T2538).

11.21. Mr Mackiewicz also telephoned Mr Sharp after this incident and told him that, although he felt some pressure from Mr Brougham, 'once…Mr Brougham had seen the circumstances, he then sort of said to Ben that perhaps it was the right thing he'd done…' (T2400).

11.22. The significance of the incidents in June 1999 and January 2000 is that it had been suggested that Mr Mackiewicz might have been influenced in the decision he made on 31 May 2000 by what happened on 7 January 2000 (see, for example, Mr Fearon's evidence at T4547).

11.23. None of the counsel before me have submitted that Mr Mackiewicz may have failed to notify Air Services or otherwise acted out of fear of the consequences from Mr Brougham in light of his experiences. This was rejected out of hand by all who knew Mr Mackiewicz. For example, Mr Sharp said:

> 'He would have done what he possibly could and with every degree of professionalism, but he wouldn't have been thinking about what someone would say, Ben was bigger than that.' (T2402)

11.24. In light of all this evidence, and in particular the outcome of the Maitland incident on 7 January 2000, I am not persuaded that Mr Mackiewicz would have been influenced in any way by what happened in these incidents. In particular, the Maitland incident was unique in that the damage to the cowling of the left engine was so extensive, and created so much drag, that the aircraft would not have maintained altitude even if the other engine was functioning perfectly. The damage would have been apparent to him at the time. I am confident that Mr Mackiewicz would have assessed the ability of MZK to fly on one engine by reference to the performance of the aircraft on the day, rather than what happened in January 2000.

11.25. <u>8 February 2000</u>

On this day, pilot Mr Nick Reymond was flying VH-BYG to Cook on the Indian-Pacific railway line when he noticed that the oil temperature on the left engine was rising, and the oil pressure was falling. On the right engine, both readings were steady (T1593). Mr Reymond also noted a drop in airspeed of 5-10 knots (T1592). He said there was no rough running (T1594). He said that he was unable to maintain full RPM on the left engine. He decided to divert to Ceduna. After landing, the engine shut down, and, due to the loss of oil pressure, the propeller feathered (T1595).

11.26. Mr Brougham said that a 'significant leak was visible on the outside of the left cowl, which would not have been visible to the pilot' (Exhibit C73e, Attachment 4).

11.27. When Mr Karl Jelinek examined the left engine of BYG in Ceduna, and later in his workshops in Port Lincoln, he found that the No.4 cylinder had a 'hole burnt into it',

(Signed)

so much so that it vented oil and lost compression. He also noted damage to the cylinder head which he thought was unusual (Exhibit C147d, p4).

11.28. Mr McHardy, the Lycoming representative, attributed this failure to a cracked spark plug, as he had in relation to the 9 September 1999 incident. Mr Brougham had similar reservations about this theory (Exhibit C73e, Attachment 4).

11.29. This incident occurred while the aircraft was in the 'cruise' phase of the flight.

11.30. 20 May 2000

On this day a Piper Chieftain aircraft VH-ODE piloted by Mr Stefan Jelinek was travelling from Toowoomba, Queensland to Moomba, South Australia when Mr Jelinek noticed that he began falling behind his accompanying aircraft. He then noticed that the engines went out of synchronisation, he reset them and they fell out again. This happened a third time, and then Mr Jelinek noticed that the manifold pressure (MP) dropped on the left engine. The oil pressure dropped, and the oil temperature increased on the left engine as well. Mr Jelinek said:

> 'I recognised this as an impending engine failure and feathered the left engine. The feathering was carried out by using the standard method of pulling the throttle back, pulling the propeller pitch control to the feather position and pulling the mixture control to idle cut off.
>
> The aircraft was configured for single engine cruise by the use of the aircraft trim system. I did not need to increase the power on the right engine due to the aircraft not being heavily loaded.
>
> At this time I was between 100 and 120 nautical miles from Moomba at a cruising altitude of 10,000 feet. I did not have any passengers on board and the aircraft was performing satisfactorily on one engine, so I continued to Moomba.' (Exhibit C175, p2)

11.31. When the engine was examined, a considerable amount of 'white metal' was found in the oil filters. When stripped down, it was found that a big end bearing on the No.1 connecting rod to the crankshaft had failed, allowing oil to escape. Mr Jelinek said that Textron Lycoming refused to pay for the repairs on the basis that the engine was out of warranty (Exhibit C175, p4).

11.32. Mr Jelinek said that his company experienced problems with bearing failure in February 2002 in another aircraft (VH-OMM), when metal fragments were found in an oil filter. When stripped 'several main bearings were found to be in various stages of delamination or breaking up' (Exhibit C175, p4).

11.33. 14 December 2001

On this day, five days before the final ATSB report was published, a Piper Chieftain aircraft owned by Sharp Aviation VH-JCH, piloted by Paul Beattie with co-pilot Nathan Wileman, was flying between Avalon and Portland, Victoria. Mr Beattie had, until January 1999, been employed by Whyalla Airlines.

11.34. Mr Beattie said that they initially had problems keeping the engines synchronised with the RPM on the right engine fluctuating. He then noticed from his instruments that the right engine vacuum/pressure pump had failed, that the right engine CHT was lower than normal, the right engine oil temperature was high and the oil pressure was falling. Mr Beattie concluded that the right engine was about to fail, so he closed down the engine and feathered the propeller in accordance with standard procedures. He set the left engine to 75% power (33 inches MP, 2,400 RPM, mixture full rich) and, maintaining airspeed of 120 knots, diverted to Warrnambool, where they landed safely (Exhibit C174a, p2-3).

11.35. Mr Sharp, the Managing Director of Sharp Aviation, said that when the engine was stripped down it was noted that the crankshaft had fractured at the No.6 connecting rod big end journal, an almost identical failure to that of the left engine in MZK on 31 May 2000.

11.36. Mr Sharp said that the engine was impounded by the ATSB on 17 December 2001. He said that Dr Romeyn told him that the damage was similar to that of MZK, that it looked as if it was caused by leaning, and that there was some evidence of lead oxybromides in the cylinder. Mr Sharp said that his company used conservative leaning techniques, after which Dr Romeyn did not pursue the subject (Exhibit C179, p4)

11.37. Mr Sharp said that by March 2002 the ATSB indicated that they did not propose to carry out a detailed analysis of his broken crankshaft, even after the recall of similar units by the Lycoming factory on 1 February 2002. Mr Sharp said he found this confusing in light of the similarities with the MZK crankshaft (Exhibit C179, p4).

11.38. The ATSB issued an 'Accident and Incident Report' concerning this incident which reads:

> 'The engine components were sent to the ATSB for further technical analysis. Analysis of the fracture indicated that fatigue cracking had initiated below the surface of the journal, associated with a discontinuity in the nitrided surface zone, at the transition from the journal to the forward fillet radius. The number-6 connecting rod bearing inserts had been destroyed during operation; the remnants included flattened fragments of steel backing material. In addition, fatigue crack growth has commenced at the centre of the connecting rod cap, most probably after the bearing inserts had failed.
>
> Because of the small amount of bearing debris available for testing, the reason the number-6 bearing inserts failed could not be determined.
>
> This engine failure is one of a number of events being used in a detailed safety study of failures to high powered piston engines. On completion, the results will be available on the ATSB website www.atsb.gov.au or from the Bureau on request.'
>
> (Exhibit C177d)

This 'detailed safety study' has not been completed since that time.

11.39. Dr Romeyn, the ATSB metallurgist, had been responsible for examining these engines. He said that the crankshaft fracture was clearly a result of fatigue crack propagation, and agreed that the features were very similar to that of MZK (T4060). The bearing inserts in the No.6 connecting rod journal had also been reduced to fragments. The connecting rod had not made a hole through the crankcase as it did in MZK (T4060). There was 'some evidence' of a planar discontinuity extending from the surface down through the nitrided layer to the point of fatigue crack initiation, as with MZK. There was evidence of some distress in other bearing surfaces, there was evidence of movement of the bearing inserts and there was evidence of the presence of the anti-galling compound.

11.40. Dr Romeyn said that having regard to the report of the pilot and co-pilot that the right engine was shut down after it had been showing signs of fluctuation in the engine RPM, it was clear that the crankshaft had not separated into two pieces, and had remained 'dogged' for a period of time, which was consistent with the ATSB conclusion in relation to MZK (T4062).

11.41. Dr Romeyn acknowledged that Sharp Aviation did not lean their engine to the same extent as Whyalla Airlines did, although he was unable to assess the significance of that difference (T4063).

(Signed)

11.42. Mr Sharp was not satisfied with this outcome, so he instigated his own investigation by commissioning, at his own expense, a report from Mr Ron Murphy of Australian Automotive Solutions.

11.43. Mr Murphy is a qualified Mechanical Engineer who has specialised in Automotive Engineering for more than 30 years. This was the first time he had worked on an aircraft engine (T2143). For the purposes of this inquiry, I will work on the basis that the principles involved are the same. No party has suggested to the contrary.

11.44. Mr Murphy's findings were as follows:

- He detailed the damage noted to the bearings, connecting rods, pistons and crankshaft due to the flailing of the connecting rod after the end cap of the big end came away;
- There was a substantial drop in the crown hardness of all the pistons noted, especially numbers 2, 4 and 6. He said:

> 'The under crowns of these pistons are also showing signs of piston crown over heating. The crankshaft failure has taken place through the number six big end journal. From the beach marks on the fractured surface it is clear that this failure has been caused by a fatigue crack. It is also clear that this fatigue crack has started near the fillet radius, at the edge of the journal and at the lowest point of this journal, when it is in its TDC position. Microscopic examination of this fractured surface reveals that this fatigue crack actually started at a very small void (flaw) in the journal surface, approximately 0.8 mm below the surface of the fillet radius. This fatigue crack appears to have initially developed relatively slowly. However, after extending out radially some 2.5 mm, its progression has then accelerated, covering at least 60% of the fractured surface before the crankshaft finally broke.' (Exhibit C177)

11.45. Mr Murphy concluded:

> 'From the observations and measurements made, it is my opinion that the primary cause of this engine failure was the void or flaw, and its particular location within the crankshaft's big end journal. This flaw was in affect a stress riser, which created a starting point for the fatigue crack.
>
> There is also a secondary factor that must be considered as a likely contributor to the initiation of this fatigue crack, and that is abnormal combustion. From the condition of the pistons, connecting rods and five other big end bearings, it is evident that substantial abnormal combustion was taking place this engine, especially in the bank containing cylinders two, four and six.
>
> Abnormal combustion, when it occurs, creates extremely high temperatures and pressures in the combustion chamber. It is these conditions that can lead to the softening

of piston crowns, over heating of the piston's under crown and connecting rod's small end, and the over loading of the engine's big end bearings.

The sequence of events that caused all the damage to this engine were as follows:-

1. The start of a fatigue crack from the void in the crankshaft's number six journal. (The particular location of this void was at the highest region of tensile loads on this journal. Any excessive piston loads would also have increased these tensile loads).
2. Once this fatigue crack had extended through over half of this journal, the flexing about this crack would have then caused the big end bearing to begin to fail.
3. The final failure of the big end bearing, then allowed the connecting rod's big end bore to pound against the weakened crankshaft journal. This severe abuse then lead to the failure of both the connecting rod and crankshaft.'

(Exhibit C177)

11.46. The photographs of the fractured crankshaft of JCH taken by Mr Murphy are Exhibit C177f. They are strikingly similar to the photographs of the broken left crankshaft of MZK taken by Mr Hood (Exhibit C194), which I will discuss later. The photographs are reproduced in Section 12, paragraph 12.64.

11.47. Mr Murphy did not carry out any further analysis on the nature of the 'void', which constituted the origin of the fatigue crack in JCH. Whatever its nature, Mr Murphy's opinion was clear that any such imperfection was the result of a flaw in the manufacture of the crankshaft.

11.48. Mr Murphy's results concerning the hardness of the pistons led him to conclude that there had been abnormal combustion in that engine, particularly on the bank containing cylinders 2, 4 and 6. He speculated that there might have been a leaner fuel/air mixture on that side, perhaps due to a fuel blockage on that side (T2150).

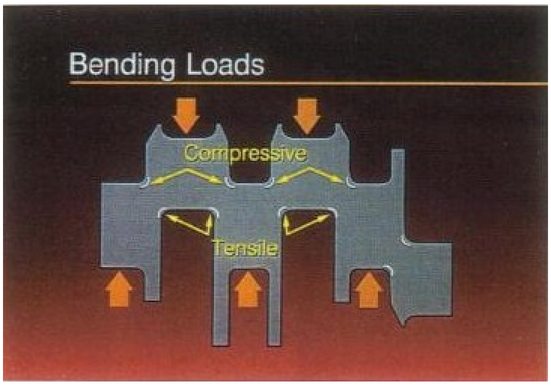
11.49. Mr Murphy was unable to say, however, whether the fractured crankshaft was related to the abnormal combustion which was evident, although that remains at least a possibility (T2154).

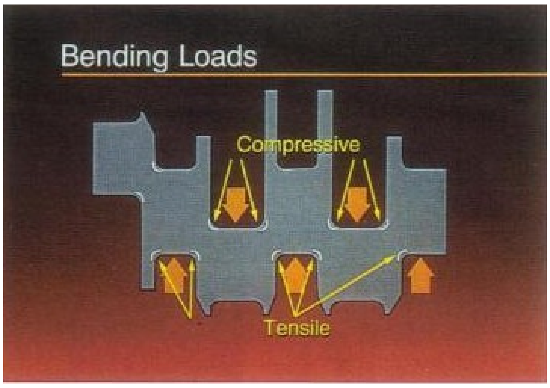
11.50. Mr Murphy did not agree with the ATSB report into the JCH failure (Exhibit C177d). In particular, he did not agree that the fatigue crack initiation was 'associated with a discontinuity of the nitrided surface zone' (T2156).

11.51. Mr Murphy also disagreed that it was possible to see fatigue cracking in the centre of the connecting rod cap at all. He said that the failure of the big end bearing and, consequently, the end cap, was due to the progressive failure of the crankshaft, and was not a separate example of fatigue failure (T2157-58).

11.52. Mr Murphy said that he saw no thermal crack from the surface of the journal down to the fatigue crack initiation point, as suggested by Mr McIlwaine SC, counsel for the ATSB. He would have expected to see one under the microscope if there had been one there (T2167, T2175).

11.53. One area where there is serious controversy between the evidence of Mr Murphy and Dr Zockel is whether the fatigue crack would propagate when the crankshaft was in compression, according to Mr Murphy, or tension, according to Dr Zockel. Their respective opinions appear to revolve around whether the 'cheeks' or webs of the crankshaft surface would tend to flex, as illustrated by Mr Murphy (T2174), or whether the journal surface itself would flex into a slight 'U' shape under compression as suggested by Dr Zockel (T3465). Mr Murphy produced diagrams from the publication 'Crankshafts-Applied Failure Analysis' (Exhibit C177c) reproduced below:





I will discuss Dr Zockel's opinions in more detail in Section 12 of this finding.

11.54. The features of the failure of the JCH crankshaft are identical, in almost every respect, with that of the left crankshaft of MZK. The failure happened only five days before the release of the ATSB final report (Exhibit C97), and more than a year after Mr McHardy notified Mr Lyons of CASA that a metallurgical problem had been identified in Textron Lycoming crankshafts in the USA, and a year after an Emergency Airworthiness Directive had been issued in relation to Teledyne Continental crankshafts. Yet the occurrence warranted no more than a $1^{1/2}$-page report, without detailed metallurgical analysis, by the ATSB, and an indication that it would be included in a larger study, which is still yet to occur.

11.55. I have already demonstrated that the ATSB conclusion in relation to the failure of the MZK crankshaft was virtually ignored by the FAA, the aviation regulator in the United States of America, because the ATSB had attributed the failure of MZK's crankshaft to 'engine detonation due to the engine leaning procedure used by several Australian operators' (Exhibit C222b, LL-4).

11.56. VH-JCH suffered a virtually identical crankshaft failure where engine leaning procedures could not be blamed (and there was no talk of lead oxybromide deposits), and yet the ATSB did not re-evaluate their conclusions.

11.57. <u>April 2002</u>

Mr Cavenagh mentioned another incident involving a Piper Chieftain aircraft, VH-LTW. He described what happened as followed:

> 'Yes, in April 2002 a Chieftain aircraft registration VH-LTW took off from King Island in Bass Strait and the take-off and initial climb were normal. When passing about 2,500 feet the crew noticed slight vibration and about a minute later felt a surge from the right engine and the engine instruments showed a falling manifold pressure for that engine. They carried out their trouble checks but were unable to rectify the situation so they decided to return to King Island, which by that time was about seven minutes flying time away. During their pre-landing checks they noted the engine oil temperature was above the red line, that's for the right engine, and they could not synchronise the propellers at 2500 rpm. The aircraft landed safely and while taxiing in they smelt burning oil and saw oil stains on the nacelle, so they shut down the engine once they were clear of the runway. Disassembly of that engine revealed that the No.3 piston had melted, the piston rings had broken and the nature of that damage was consistent with detonation.' (T3593)

11.58. Mr Cavenagh said that after LTW had landed, it had only one litre of oil remaining in the sump which means that about 11 litres had been lost in a period of about eight minutes or so, which illustrates how quickly a substantial amount of oil can be lost in those circumstances. Mr Cavenagh argued that if MZK had experienced severe detonation during climb, Mr Mackiewicz would have noticed similar signs and taken similar action to that of LTW's pilots (T3595). This seems rather speculative, and assumes that the evidence presented to the pilots in both instances was the same, whereas the size of the hole in the piston and the speed with which it developed, may not have been the same.

(Signed)

11.59. Issues, Discussion and Conclusions

11.60. *To what extent do the incidents involving VH-BYG on 9 September 1999 and VH-BYG on 8 February 2000 and VH-ODE on 20 May 2000 and VH-LTW in April 2002, suggest that the damage to the right engine of MZK on 31 May 2000 occurred in similar circumstances, that is during the 'climb' phase of flight?*

11.61. The incident involving VH-BYG on 9 September 1999 illustrates that the vibration in the left engine and, inferentially, the damage which was noted later, occurred at the end of the climb and the beginning of the cruise phase of flight. This is consistent with Mr Braly's thesis that the leaning practices of Whyalla Airlines during the climb phase of flight, may have led to detonation and consequential heat damage to the piston. The incidents on 8 February 2000 and 20 May 2000 occurred while the aircrafts were in the cruise phase, while the engine was on a relatively low power setting. This does not assist in the analysis of whether high power settings may lead to such damage. The incident in April 2002 involving VH-LTW occurred while the aircraft was in the climb phase of flight, when vibrations in the engine commenced. Once again this incident illustrates the fact that heat damage to the piston can occur during a high power setting phase of flight.

11.62. *To what extent do the events of 11 June 1999 and 7 January 2000, suggest that Mr Mackiewicz may have reacted other than appropriately to the extreme emergency which faced him on 31 May 2000?*

11.63. The events of 7 January 2000 when the left engine of MZK failed and Mr Mackiewicz performed a forced landing at Maitland, South Australia, were quite different from the circumstances on 31 May 2000. The catastrophic failure of the left engine severely damaged the engine cowling to the extent that Mr Mackiewicz was unable to maintain height. This is what led him to divert to the Maitland aerodrome. The evidence from the passengers onboard indicated that Mr Mackiewicz handled this stressful situation well and confidently. There is no evidence that he acted inappropriately in any way as a result of the incident, as alleged by the ATSB.

11.64. In relation to the two incidents on 11 June 1999 and 7 January 2000, when Mr Mackiewicz came into a position of tension with Mr Kym Brougham about his actions. I reject the suggestion that his airmanship on 31 May 2000 was adversely affected by either of these incidents.

(Signed)

11.65. *To what extent do the events of 14 December 2001 suggest that the left engine of MZK failed in similar circumstances. In particular:*

- *The fact that lead oxybromides were not implicated in the failure;*
- *The operator's leaning techniques were described as conservative;*
- *The similarity of the apparent cause of the fracture of the crankshaft.*

11.66. The features in the fractured crankshaft in VH-JCH on 14 December 2001 (the Sharp Aviation incident), are strikingly similar to the fracture of the crankshaft in the left engine of MZK on 31 May 2000. Dr Arjen Romeyn, the ATSB metallurgist who had been heavily involved with MZK, agreed that the features in the JCH crankshaft were very similar. I find it surprising that Dr Romeyn did not subject the JCH crankshaft to a detailed examination having regard to these similarities. The investigations by Mr Murphy reveal the striking similarity between the features in MZK and those in JCH, including the fact that the fracture had occurred at precisely the same location. The beach marks were very similar. The fatigue crack initiation point was almost identical. These similarities should have been clearly apparent to the ATSB.

11.67. The significance of the JCH failure, however, was that there were no lead oxybromides present and the operator's leaning techniques could not be criticised. These facts, in my opinion, undermine the theories published by the ATSB in their final report published only five days later into the failure of the MZK crankshaft.

11.68. *Was the incident on 14 December 2001 investigated thoroughly by the ATSB? If it had been, would that have assisted the investigation of the events of 31 May 2000?*

11.69. The incident on 14 December 2001 was not investigated thoroughly by the ATSB. It resulted in a three paragraph report which foreshadowed a 'detailed safety study of failures to high powered piston engines' in due course. This study has still not eventuated.

12. The Scientific Investigation

12.1. As a result of the criticism of the ATSB investigation from within the aviation community, Counsel Assisting the Coroner, Mr P W Eriksen and his Instructing Solicitor Mr N A Kernahan, arranged for a number of experts to review the scientific aspects of the ATSB investigation and provide me with their opinions. In this section I will set out the results of those investigations.

12.2. It may be helpful to set out a number of definitions at this point:

Preignition - Professor King describes preignition as follows:

'Preignition occurs if the induced ignition (i.e. where the fuel-air mixture which would not auto-ignite is ignited locally by an ignition source) is initiated by some means prior to the firing of the spark. It may be caused by overheated surfaces (overheated valve or spark plug, or glowing combustion chamber deposit) if the conditions are appropriate. The important issue is, what are appropriate conditions? As described above, a minimum ignition energy or minimum ignition temperature must be achieved. A simple interpretation is that the local gas temperature caused by the glowing surface or deposit must be similar to that caused by the normal operation of the spark plug and hence the energy should be similar to the normal spark energy……In summary, the minimum energy for preignition depends on a large number of factors, including but not limited to, burning velocity, temperature, mean reaction rate, volumetric heat capacity, thermal conductivity, pressure, mixture composition, turbulence, and location of ignition source.

Clearly, it is a complicated issue as to whether and under what conditions hot surface deposits of lead oxybromides or any other material are capable of causing preignition. The mere presence of such compounds does not automatically lead to preignition.' (Exhibit C208a, p16-17)

Preignition and engine damage – explained by the ATSB

The significance of preignition in relation to engine damage is that it occurs while the piston is still on the compression stroke, before it reaches top dead centre, thereby placing excessive loads on the piston, connecting rod, and crankshaft (see Exhibit C97, p75-77).

Detonation – Dr Zockel describes detonation as follows:

'Detonation is simply a sequence of events where the fuel and air burns very much more quickly than under normal circumstances. A large amount of fuel is burnt in a very short time. So that is detonation. It is equivalent to the normal understanding of a detonation, something that explodes. Auto-ignition is when a substance ignites and burns either with or without detonation without some external ignition source. So auto-ignition can occur when a substance is either being compressed or heated or under certain conditions, if the conditions are just right it may auto-ignite, for instance flour or certain substances can auto-ignite even under normal atmospheric conditions.' (T2044)

See also Mr Braly's definition at paragraph 12.82

End gas detonation – Dr Zockel describes end gas detonation as follows:

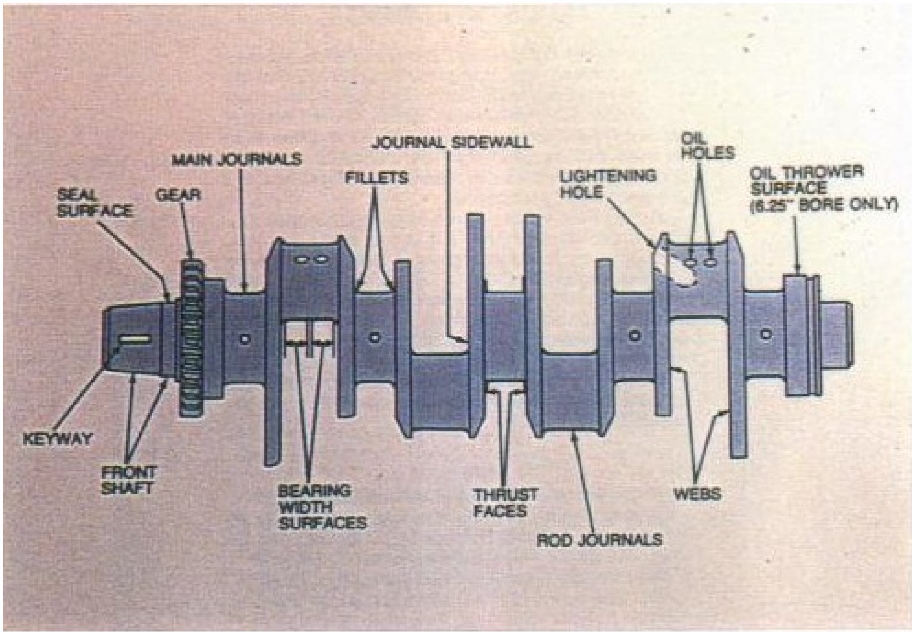
'Now, end-gas detonation or combustion knock, which does not require an external ignition source, results from a normal spark starting off the ignition process but the compression due to the burnt gases - the burnt gases compress the unburned charge and if that pressure and temperature gets sufficiently high, that unburned charge burns all of a sudden altogether, and so you can have pressure fluctuations, but this time they occur after top dead centre………with end-gas detonation, you don't need an ignition source, you're not relying on either oxybromide or any other source on the top of the piston or in the spark plug or any other source to cause that detonation to occur.' (T2088-89)

Stoichiometric mixture – Dr Zockel describes it as follows:

A stoichiometric mixture is the ratio of air to fuel in which the amount of oxygen available is sufficient to completely burn the carbon in the fuel to carbon dioxide and the hydrogen in the fuel to water vapour so that complete combustion is achieved. Dr Zockel explained that in relation to most fuels, that ratio is around 14.5-14.7 to 1 (that is 14.7 kilograms of air to one kilogram of fuel). (T2100)

It is the concept of the stoichiometric mixture which forms the basis for any discussion of the air/fuel mixture. For example, on a number of occasions I have referred to the mixture being either 'rich' or 'lean' and that refers to whether the ratio of air to fuel is lower or higher than that theoretical stoichiometric point.

12.3. A 'crank' is described in the Shorter Oxford English Dictionary as 'a portion of an axis bent at right angles, used to communicate motion, or to change reciprocal motion into rotary motion, or the converse'. In the case of an aircraft piston engine, it is the function of the crankshaft to convert the reciprocal motion of the pistons, created by the explosion of the fuel within the cylinders, into rotary motion to drive the propeller and auxiliary functions such as fuel pumps, magnetos, etc. A diagram explaining the various features of a crankshaft is contained in Exhibit C177c and is reproduced below:



(Signed)

12.4. Professor King's investigations

Professor Keith King is Head of the School of Chemical Engineering at the University of Adelaide. He received his PhD in 1968 and has progressed from the position of Lecturer in Chemical Engineering at the University of Adelaide in 1971 to Head of the Department in 1988 to 1990, and 1999 to 2001. He has held a number of Visiting Professorships around the world, and is a member of a number of professional and scientific societies and has received numerous academic and professional awards and honours. He has been published widely. The central theme of his research activities has been the chemistry of combustion reactions, including 'the chemical reactions that occur during combustion processes, how fast they proceed, the types of reactions that occur, the different pathways they might undertake' (T3432). He has been an expert in this field for nearly thirty years. I regard Professor King as being extremely well qualified to comment upon the chemical engineering aspects of the engine failures suffered by MZK on 31 May 2000.

12.5. Professor King addressed the conclusion made by the ATSB that, in relation to the failure of the left engine:

> 'The Number 6 bearing insert was damaged during engine operation through the combined effect of:
>
> - high bearing loads created by lead oxybromide deposit induced preignition, and
> - lowered bearing insert retention forces associated with the inclusion of an anti-galling compound between the bearing inserts and the housings.' (Exhibit C97, p vii)

12.6. The ATSB did not attribute the failure of the right engine of MZK to lead oxybromide deposits. Indeed, the ATSB concluded that the 'carbonaceous nature of the residual deposits on the piston crowns (of the right engine) indicated that detonation had occurred under a rich fuel-air mixture setting. Rich mixture settings are used with high engine power settings' (Exhibit C97, p vii). This is to be contrasted with their assertion that lead oxybromide deposits, which were more likely to be the consequence of operating the aircraft with an excessively lean fuel-air mixture, contributed to the left engine failure.

12.7. Dr King said that the damage to the No.6 piston in the right engine was due to end gas detonation, which is a function of increasing temperature and pressure, and does not require an ignition source as preignition does (T3454). Lead oxybromides were therefore irrelevant to the failure of the right engine.

12.8. The ATSB explained this process at pages 75 and 77 of the final report. In summary' tetraethyl lead (TEL) is added to aviation gasoline to improve the detonation resistance of the fuel. However, lead oxides are produced in the combustion process which can form deposits in the combustion chamber and damage components, and may also cause preignition. In order to get rid of these deposits, ethylene dibromide ($C_2H_4Br_2$) is used as a scavenging agent in aviation fuel to form a volatile compound called lead bromide which is removed from the combustion chamber with exhaust gases. However, if that ideal result has not achieved, a variety of lead compounds may form including lead monoxide (PbO), lead bromide ($PbBr_2$) and complex lead oxybromides. (Exhibit C97, p76)

12.9. The ATSB report states that the incandescence of these deposits may have led to preignition of the fuel-air mixture (Exhibit C97, p76).

12.10. The ATSB report asserts that:

> 'Chemical analysis of deposits removed from the pistons of a number of high-powered turbo-charged engines has identified that complex lead oxybromide compounds were formed…….The tan coloured deposits prevalent on the piston crowns of these engines was found to be homogenous and was identified as $Pb_3O_2Br_2$ (or $2PbO.PbBr_2$). Examples of these deposits are shown in figure 47.' (Exhibit C97, p77)

12.11. However, Exhibit C97 does not contain any results upon which these conclusions are based, and none of the piston crown deposits shown in Figure 47 of the report are from the engines of MZK.

12.12. When the supporting research documentation was eventually received from the ATSB, Professor King noted that an analysis was carried out by 'a group of five appropriately qualified scientists from the ANU and the University of Canberra (UC)'. The ATSB supplied six pistons to the group, namely VH-BNN No.3, VH-ASE No.1, VH-MZK No.2, VH-MZK No.6 (left engine), VH-ODE No.5, and VH-RNG No.3. VH-MZK No.2 had been taken from the left engine of MZK which failed on 7 January 2000 leading to the forced landing at Maitland. VH-MZK No.6, left engine, was taken from the engine which failed on 31 May 2000.

12.13. The research showed that the major constituent of a tan coloured deposit on each of the six pistons tested was $Pb_3O_2Br_2$. There is no mention in any of the supporting documentation that material from any of the other piston crown surfaces of MZK were tested (see the evidence of Dr Romeyn at T4289).

(Signed)

12.14. Professor King conducted a search by scanning electron microscopy at the Centre for Electron Microscopy and Microstructure Analysis (CEMMSA) at the University of Adelaide, which Professor King describes as 'arguably the best facility of its kind in Australia and one of the best in the world'.

12.15. This research disclosed that samples from piston No.'s 1, 3 and 6 from the left engine and No.3 from the right engine of MZK produced no sign of lead oxybromide whatsoever. A set of thirteen samples taken from the piston crown of No.6 left engine were analysed later, and in none of the thirteen samples was lead oxybromide located.

12.16. The sample from the ANU was analysed and this disclosed the presence of lead oxybromide compounds, although not $Pb_3O_2Br_2$. The relative atomic abundance was more consistent with $Pb_5O_6Br_2$, and $Pb_4O_7Br_2$. However, Professor King acknowledged that scanning electron microscopy is not as accurate as x-ray powder diffraction, the technique used at ANU (T3440).

12.17. When asked to comment on why lead oxybromide was found in the one sample from MZK's left engine No.6 piston taken by the ANU, but not in thirteen others, and no lead oxybromide was found on the other four pistons tested, Dr King described these results as 'very puzzling' (T3434).

12.18. Another disturbing feature of the ATSB testing was that there was no record kept of the precise location where the sample was taken which led to the single positive result, which is a departure from good scientific method (T3442).

12.19. On the basis that the only lead oxybromide present in either of MZK's engines was found on the No.6 piston crown on the left engine during the ANU study, it is fair to conclude that there was only a very small amount of lead oxybromide present. For this reason, and because lead oxybromides were found on pistons from other aircraft, it seems unlikely that the bromides were present as a result of the immersion of the engines in seawater (T3443).

12.20. Professor King made a number of other criticisms of the scientific methods adopted by the ATSB technicians in reaching their thesis, but for the purposes of these findings, it is not necessary to discuss them here.

(Signed)

12.21. Professor King's conclusions

As to the conclusion of the ATSB that one of the factors leading to the failure of the left engine was 'the accumulation of lead oxybromide compounds on the crowns of pistons and cylinder head surfaces':

- Professor King said that there is no evidence whatsoever that there were lead oxybromides on any of the cylinder head surfaces of VH-MZK (Exhibit C208a, p12);
- If there were lead oxybromides present they were confined to one small area on the piston crown of the No.6 piston, left engine, which coincidentally was the spot where the ANU took one of two samples, leaving nothing on the rest of the piston crown and nothing on any of the other pistons tested in either engine (Exhibit C208a, p13);
- The tan coloured deposits referred to in Figure 47 of the ATSB final report (Exhibit C97) were not found in VH-MZK's engines and it is not possible to compare them with MZK's piston crowns as the magnification in the photographs in Figure 47 is not stated (Exhibit C208a, p12);
- Even if lead oxybromides had been present on the piston crowns in the left engine, there is still not enough material from which it could be concluded that they are relevant to the issue of preignition. Professor King said:

> 'It is not just the temperature of the deposit that's important, it's also the mixture composition so what one needs to reach what is called the minimum ignition energy which depends on the pressure, it depends on mixture composition, it depends on temperature, how many different deposits you might have; it's a very complex issue and one could not say simply because you have one deposit of lead oxybromides that it will cause pre-ignition' (T3451-52)

- Professor King concluded:

> 'This evaluation, combined with the results of the SEM analyses presented in Section 3 above must cast considerable doubt on the ATSB conclusions that lead oxybromide compounds were present in sufficient quantity to play a significant role in the failure of the left hand engine of VH-MZK.' (Exhibit C208a, p13)

12.22. Dr Zockel's investigations

Dr Manfred Zockel holds a PhD from Cambridge University in Mechanical Engineering, and is a Fellow of the Royal Society in Arts. He has published many research papers over the years and has been associated with the University of

Adelaide since 1973. He rose to the position of Associate Professor but, since his retirement, holds the position of Honorary Visiting Research Fellow. One of his major interests has been the mechanical engineering aspects of the internal combustion engine.

12.23. Dr Zockel had access to the engine parts from MZK after they were delivered to Adelaide in March 2002. Following his examination of those materials and as a result of a number of questions posed to him by Counsel Assisting, Dr Zockel prepared a report which is Exhibit C176.

12.24. Failure of the left engine

Dr Zockel explained that because the fatigue crack in the crankshaft in the left engine commenced on the underside of the journal (that is, the underside when the piston is at top dead centre, at the point where the piston is at the top of its stroke and the connecting rod is vertical), in his opinion the fatigue crack could not have propagated while the journal was being compressed (i.e. during the combustion phase). Dr Zockel's opinion was that the fatigue crack was more likely to have propagated as a result of the inertia forces exerted on the journal during the other three strokes of the piston which put the underside of the journal in tension rather than compression (T2046).

12.25. On Dr Zockel's reasoning, abnormal combustion, as postulated by the ATSB, played no part in the failure of the crankshaft in the left engine (T2047).

12.26. It will be recalled that Mr Ron Murphy, the engineer who examined the Sharp Aviation engine following the incident on 14 December 2001 involving VH-JCH, which he described as almost identical with the failure in MZK, gave a different opinion. Mr Murphy's thesis was that the fatigue cracking was propagated by compression forces because, in his opinion, the vertical 'webs' of the crankshaft were more likely to flex than the horizontal journal during the compression phase and this flexing would cause tension rather than compression at the point indicated by Dr Zockel and thereby propagate the fatigue crack. While there is direct conflict between Mr Murphy's opinion and that of the ATSB about how the fatigue crack initiated (i.e. whether the weakness was due to a subsurface anomaly in the steel or a thermal crack), Mr Murphy's theory as to compression forces causing the crack to propagate does not discount abnormal combustion causing undue compression forces as being relevant, whereas Dr Zockel's view does.

12.27. Dr Zockel explained that the manner in which the fatigue crack propagated through the journal to approximately half way, and at an angle of about 15° to the webs on each side, indicates that the forces acting upon the journal were not simply bending, but also had a torsional shear component (T2050). This is demonstrated in the ATSB report Exhibit C97, figure 31, page 57.

12.28. Dr Zockel thought that, by the time the last flight of MZK departed Adelaide at around 6:20pm on 31 May 2000, only 25-30% of the crankshaft journal was intact (T2060 and T3477).

12.29. As to the failure sequence of the left engine, Dr Zockel contended that it is not possible to determine whether the journal completely failed first, or whether it remained 'keyed together' by the end cap of the connecting rod remaining intact, and the final failure did not occur until the end cap failed as a result of the bearings being 'machined out' by the steadily failing crankshaft within, eventually producing the same result. He said:

> 'They are both possible but for the bearing failure to occur at the same time and the same place as the fatigue (crack), the probabilities are very much less, and so I would say on the basis of probability that the crack in the journal resulted in the failure of the bearing. But in the end it was the bearing had to let go completely - the big end had to basically be destroyed for the crankshaft to actually come apart.' (T2063)

12.30. Dr Zockel explained that once there was a full separation of the two pieces of the crankshaft, all of the auxiliary functions of the engine, which are connected to the aft end of the crankshaft, would have failed. These would have included the camshaft, magnetos and oil pump, and as a result of this the engine would have stopped immediately, within seconds (T2071).

12.31. Dr Zockel summarised his opinion in relation to the left engine as follows:

> 'In summary it is my opinion that there are two possible primary causes of the failure of the left hand engine:
>
> (a) The higher probability is that the crack in the crankshaft caused the failure of the bearing. The bearing surface would have been removed in fine particles which would have been washed out with the oil, while the rest of the bearing would then have failed due to overload and breakdown of the hydrodynamic film. The

combustion forces could not have contributed to the propagation of the fatigue crack because the location of the fatigue crack is in compression when the combustion forces act.

(b) The second possibility is that the bearing failed due to delamination of the aluminium-tin bearing layer. Again the parts would have been washed out by the oil flow and the increased gap would have destroyed the bearing inserts, broken the bolts and the end caps, all in a relatively short time. In this scenario the combustion forces could have played a role but it is also possible that the bearings were inadequate for the engine forces and that normal combustion forces overloaded the bearings. However, it must be stated that there is no evidence of imminent bearing failure of any of the other big end or main bearing inserts.

It must also be mentioned that the position of the crankshaft failure is not the most highly stressed area in the crankshaft which would suggest that the normal operating forces were not the primary causes.

This leaves material properties as the most likely suspects for the fatigue failure.'

(Exhibit C176, p6)

12.32. Dr Zockel said that he did not believe that the bearings would have been damaged or destroyed as a result of preignition. He said:

'We see on the right-hand engine that where there was undoubtedly detonation, whether it was pre-ignition or otherwise, the bearings were fine. There was no damage to the big-end bearings or the crankshaft, so detonation doesn't necessarily mean a damaged bearing.' (T2079-80)

12.33. Right Engine

Dr Zockel said that it is clear from an examination of pistons No.5 and No.6 in the right engine, and in particular the melted piston edges, that the right engine had experienced detonation. He said that the rough appearance of the melted parts indicated that the detonation was in the form of end gas detonation rather than preignition.

12.34. Dr Zockel explained that because the sandblasted appearance of the No.5 and No.6 cylinders in the right engine was due to end gas detonation, which does not require an external ignition source, he was able to dismiss the theory that the detonation process was due to deposits on the pistons (T2088). He said:

'Combustion knock (end gas detonation) is facilitated by mixtures that ignite easily, such as those close to stoichiometric, or those having low octane number fuels.'

(Exhibit C176, p7)

12.35. Dr Zockel said that end gas detonation can be caused or exacerbated by a number of things:

- The level of swirl or turbulence in the combustion chamber;
- The large diameter of the cylinders in this engine, particularly if one spark plug is inoperative for whatever reason;
- If the spark timing is inappropriate, particularly if it is too far advanced.

(Exhibit C176, p7)

It is an unfortunate aspect of the ATSB investigation that the spark timing was not examined on either of these engines.

12.36. A further suggestion made by Dr Zockel as to how the end gas detonation may have occurred is that the engine may have been operated with an air/fuel ratio which is too close to the detonation limits of the engine, which is on the lean side of the stoichiometric ratio. Dr Zockel explained that during takeoff, the aircraft was operated at 'full rich', which, on his calculations, was a mixture which is about 30% richer than stoichiometric. However, during the climb phase of flight when the fuel flow is reduced as I have already outlined, the mixture more closely approaches the detonation limits of the engine. He said:

> 'Take-off is fully rich and the climb, I understand, the fuel flow is reduced and it really depends on how much it is reduced as to how close you are getting to the detonation limits, depending on the boost, depending on the revs and all those sorts of things, and if the engine is going to detonate naturally with two spark plugs operating then it is more likely to be in that phase than the maximum power take-off. I don't know what air/fuel ratio this engine was operating during climb, but it was more the probable operating regime where detonation is likely to occur.' (T2107)

12.37. These phenomena were demonstrated graphically by Mr Braly during the hearing in Oklahoma, USA.

12.38. Dr Zockel postulated that if detonation occurred during the climb phase, sufficient to deposit aluminium on one of the spark plugs, then this may have exacerbated end gas detonation even further and caused further damage to the piston. This may also have caused detonation to continue during the cruise phase of flight, when the power settings were much lower (Exhibit C176, p8).

12.39. As to the mechanism of engine failure from there, Dr Zockel's opinion is as follows:

> 'Once the piston was sufficiently damaged to allow the charge to enter the crankcase the compression in this cylinder would have been significantly reduced and the engine power would have dropped. The gas flow through the crankcase would have carried out oil mist through the breather pipe until the oil level fell below the oil pump intake pipe. The lack of oil pressure would then also feather the propeller and so effectively become an engine failure although the engine would have been capable of delivering power until the engine seized due to lack of oil. There is no evidence of any seized components.'
>
> (Exhibit C176, p8)

12.40. Conclusions

From all of the above, it can be concluded from Dr Zockel's evidence as follows:

- The fatigue crack which caused the failure of the crankshaft in the left engine was not initiated during the combustion stroke of the engine, and hence any suggestion that abnormal combustion was occurring in that cylinder is irrelevant;
- The fracture of the crankshaft was not due to bearing failure or thermal cracking at the No.6 journal in the left engine;
- The fatigue cracking in the crankshaft led to failure of the bearings rather than the other way round;
- The appearance of the No.6 piston in the right engine suggests that it was damaged as a result of end gas detonation;
- End gas detonation does not require an external ignition source, so any discussion of lead oxybromides in relation to the right engine is irrelevant;
- End gas detonation was more likely to occur during operation of the engine at settings approaching the detonation limits for the engine, which most probably occurred during the climb phase of the flight.

12.41. Dr Powell's investigations

Dr Graham Powell is a Research Fellow in the Department of Mechanical Engineering at the University of Adelaide. Dr Powell has been a Research Metallurgist since the late 1950's and has held a number of senior positions with scientific organisations such as AMDEL and CSIRO. He obtained his PhD in metallurgy from the University of Queensland in 1967.

(Signed)

12.42. Dr Powell has extensive experience in forensic metallurgy and has given evidence as an expert witness in courts at all levels in several states of Australia and the United States of America. Dr Powell was asked to comment on the metallurgical issues arising out of this incident, and in particular the issues discussed in the ATSB report (Exhibit C97), and subsequent investigations.

12.43. <u>Oxide inclusions</u>

Dr Powell explained that an oxide inclusion is a particle of metal oxide which can be found within steel. He explained that such a particle can be created when the steel solidifies, or during the rolling or forging processes (T3380).

12.44. The steel used in aircraft crankshafts is commonly designated 4340 which is an American specification. Dr Powell said that the Metals Handbook, 8th Edition, Volume 1 entitled, 'Properties and Selections of Metals', published by the American Society of Metals in 1961, at page 224, specifies that the maximum permissible size for oxide inclusions in 4340 steel is 8 microns, and that once this level is exceeded, the fatigue strength of the metal decreases significantly (T3381).

12.45. Dr Powell examined the fractured ends of the crankshaft from the left engine of MZK together with a sample taken from the No.5 journal of the same crankshaft and mounted in bakelite by the ATSB (Exhibit C218). These specimens were examined under a reflected light microscope.

12.46. The ATSB had the sample analysed at Spectrometer Services Pty Ltd (their report is part of Exhibit C213), and, according to the ATSB, it was found to have been within specified limits. Indeed the ATSB was informed by Dr Yoon Kim, the Manager of Textron Lycoming's Materials Laboratory in Williamsport, Pennsylvania, USA during his visit on 16 and 17 August 2000 that the crankshaft complied with the manufacturer's standards, although Dr Romeyn did not make a note of what precisely those standards were (T4103). This resulted in the paragraph at page 62 of the ATSB final report:

> 'The fractured crankshaft manufacture, Serial Number V537912936, complied with the engine manufacturer's proprietary manufacturing standards concerning steel quality (chemistry, strength, non-metallic inclusion content), journal surface nitriding and journal diameter).' (Exhibit C97, p62)

12.47. In summary then, the ATSB investigators accepted Dr Kim's assertion to that effect at face value and incorporated it within their report.

12.48. The ATSB metallurgist who took the sample from the crankshaft examined it at up to 500 times magnification and found no oxide inclusions in the sample (see the evidence of Mr Neville Blyth at T3857-60). This evidence was confirmed by Dr Arjen Romeyn, who was overseeing the testing process (T4045). This part of the process was also carried out in the presence of Dr Yoon Kim. I assume that he did not see any inclusions either, although this cannot be established since Dr Kim was not made available to give evidence.

12.49. Dr Powell and Mr Alasdair McLean, a doctoral student who was assisting him, ground and polished the sample again, since it was in an etched condition when received from the ATSB. After grinding and polishing, they examined the samples under the reflected light microscope, and found 'grey particles' approximately 4 millimetres below the nitrided surface and at the nitrided surface of the sample. These particles were particularly concentrated in two groups approximately 7 mms apart. He said that the clusters were slightly larger than 1 mm across and individual particles were approaching 100 microns. Taking a cluster of up to 1 mm across, which is 1,000 microns, this massively exceeds the 8 micron limit described above (T3386).

12.50. Dr Powell said that even one of those particles of 100 microns would have been enough to substantially reduce the fatigue strength of the crankshaft and a cluster of such particles would have an even greater effect (T3387).

12.51. Dr Powell said that the grey particles were examined under a field emission scanning electron microscope which established that there was a substantial presence of oxygen in the particles which led Dr Powell to conclude that these particles were indeed oxides. He said that the particles were formed as a result of oxidation at high temperatures and not as a result of corrosion using concentrated hydrochloric acid (T3389-90).

12.52. By the time Dr Powell gave evidence at the inquest, I had travelled to the United States of America and heard evidence from Mr Mark Hood, a metallurgical engineer attached to McSwain Engineering Inc, an organisation that had been requested to perform further testing of the engine components from MZK. Mr McIlwaine SC, counsel for the ATSB, suggested to Mr Hood that the grey particles found by Dr Powell were not high temperature oxide inclusions, but rather were the result of corrosion caused by concentrated hydrochloric acid (T2984). Hydrochloric acid is one of the components of a substance known as 'Marbles Reagent', which was used by the ATSB as an etchant during their examination of the sample, although Mr McIlwaine SC did not mention that substance when he was questioning Mr Hood. The theory was put forward that some of this acid had collected in the gap between the sample and the bakelite mount, and had seeped out during storage and/or transit and had resulted in corrosion.

12.53. When Dr Powell gave evidence, it was put to him that on the x-ray spectra produced by the scanning electron microscope, there appear very small peaks at the position on the spectra which indicate the presence of chlorine (see Exhibit C207b, p11-13).

12.54. Dr Powell rejected the suggestion that these particles could have been caused by hydrochloric acid. He said that if that had been the case, the peaks for chlorine on the spectra would have been the same size if not higher than the peaks for oxygen. In fact, the peaks for oxygen are very much higher than those for chlorine. He speculated that the small peaks for chlorine indicated on the spectra may be due to subsequent contamination of the oxide inclusions by hydrochloric acid (T3390).

12.55. As to the ATSB's theory that the hydrochloric acid had become trapped between the steel sample and the bakelite mount, Dr Powell rejected this as even a remote possibility. He explained that the sample is 'hot mounted' so that there is no gap between the steel sample and the mount (T3392).

12.56. Much time was taken up during the inquest examining this issue. At this stage, it is sufficient to record that after Dr Romeyn and Mr Blyth gave evidence, it was agreed that Dr Romeyn would join Dr Powell and Mr McLean, and further examination of the bakelite sample would be carried out in an attempt to resolve this controversy.

12.57. This testing took place in December 2002 at the Adelaide University. The bakelite samples were ground and polished and examined sequentially until the material was exhausted.

12.58. Following this further testing, Dr Romeyn changed his position somewhat, and withdrew the suggestion that this corrosion was due to hydrochloric acid as part of

Marbles reagent. A further statement from Dr Romeyn submitted through Mr McIlwaine SC (Exhibit C219e) states:

> '10.1 Following open candid discussions, review of test results and methods it was agreed that the presence of the grey iron oxides in the specimen may be related to one of two mechanisms, oxidation at high temperature or corrosion:
>
> 10.1.1 Dr Powell still holds the opinion that the large grey coloured abnormalities are iron oxides created during crankshaft high temperature manufacturing processes.
>
> 10.1.2 Dr Romeyn is of the opinion that the grey coloured anomalies which he has viewed under the light optical microscope on two occasions at the Adelaide University engineering department are iron oxides as a result of localised corrosion created by the action of water vapour (humidity) on the specimen surface.
>
> 10.1.3 Dr Romeyn is of the opinion that the grey abnormalities are iron oxides caused as a result of corrosion as referred to above. However, he agrees that the corrosion is unlikely to be caused by the Marble's reagent infiltration of the crack between the specimen and the Bakelite sample or that this has as a result of capillary action gravitated to the sides and surface of the specimen causing the corrosion.
>
> 10.2 The detected presence of Chlorine in some 'inclusions' is most probably (greater than 75%) related to the presence of residual chemical species from the Marble's macro-etchant.
>
> 10.3 With regard to the cluster of smaller oxide 'inclusions' observed approximately 4mm below from the surface of the journal radius and away from the other oxide 'inclusions':
>
> 10.3.1 Dr Powell considers that these oxides have formed as a result of processing at high temperatures.
>
> 10.3.2 Dr Romeyn considers that it is possible that these oxides had been formed as a result of localised corrosion.
>
> (Exhibit C219e, p7-8)

12.59. Dr Powell explained that the relevance of the presence of oxide inclusions in the bakelite sample which is taken from the No.5 fillet radius is that when the crankshaft is being manufactured, a crack can form during the casting process at elevated temperature, and the surfaces of the crack can become oxidised rendering the steel prone to flaking or 'cold cracking'. If such a cold crack runs to the surface, any subsequent reheating of the forging will oxidise the surface of the crack again, so that any subsequent deformation through rolling or forging will produce a seam with oxide inclusions spread out along the seam (T3401). The photograph reproduced below (Exhibit C207e) demonstrates (by following the broken white line) that the point

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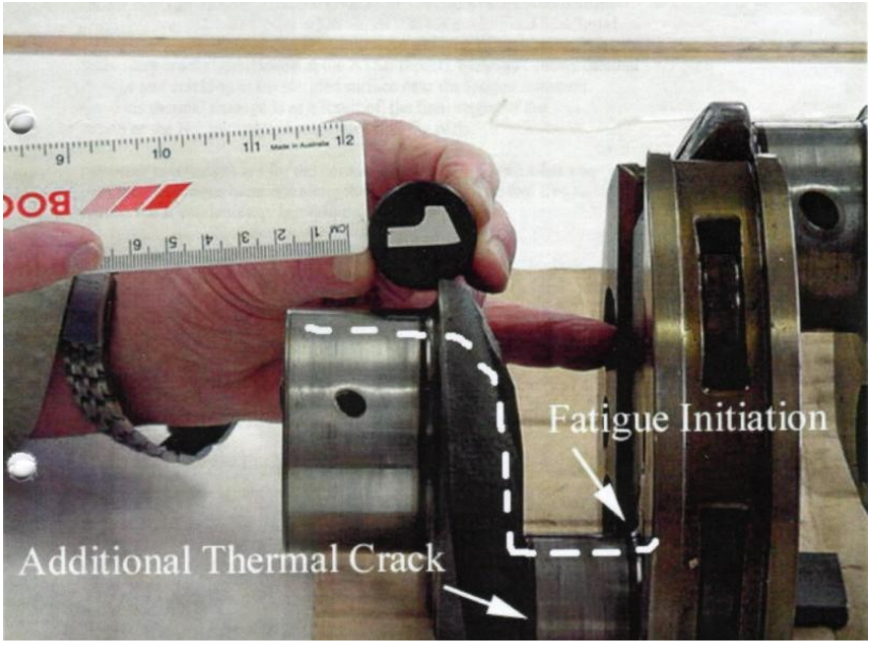
where the sample was taken from the No.5 fillet radius is in the same seam as the point at which the fatigue cracking initiated, as indicated by the white arrow.



12.60. Accordingly, it can be argued that the presence of oxide inclusions in the No.5 fillet radius, as demonstrated by Dr Powell, could lead to the inference that similar inclusions were present at the fracture site. When the fracture site was examined, no such inclusions were found. Dr Powell said that the only way of establishing whether such inclusions were present at the fracture site would be to further test by polishing the fracture site down to the fracture initiation point, which in the process would destroy it (T3409). As I will relate in due course, this testing was subsequently undertaken.

12.61. <u>Cause of the crankshaft fracture</u>

I have already outlined that the ATSB's conclusion was that fatigue cracking was initiated by the presence of a planar discontinuity in the journal surface caused by localised thermal expansion following contact with the edge of the No.6 connecting rod big end bearing insert.

12.62. Dr Powell disagreed with that analysis. He argued that any thermally induced cracking would have occurred circumferentially around the crankshaft, rather than radially. Secondly, he argued that a thermally induced crack on a nitrided surface would have been intergranular through the prior austenite grain boundaries by iron nitrate, as was the case with other thermal cracks in the crankshaft which occurred

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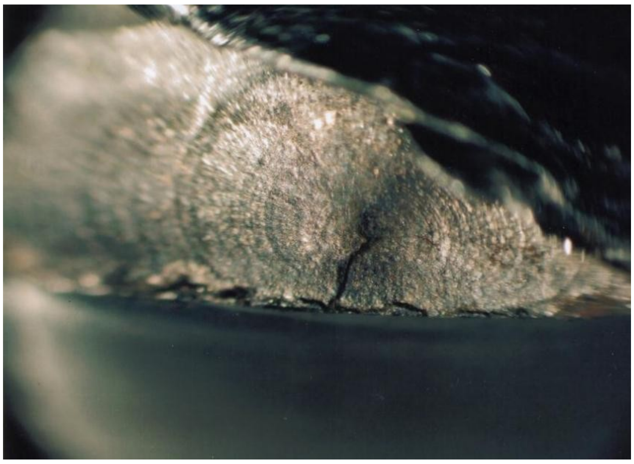
after the crankshaft failed (T3399-3400). An explanation for this highly technical analysis is at T3411.

12.63. Dr Powell said that if the fatigue fracture of the crankshaft had been initiated by a thermal crack through the nitrided surface, it would have had the appearance depicted in photograph Exhibit C207d, which depicts thermal cracking which occurred after the crankshaft failed. The initiation of the fatigue fracture site did not have that appearance (T3417-18). He added that any thermal cracking which did appear on the nitrided surface of the crankshaft affected no more than about 10% of the nitrided layer, which is less than 1 millimetre in depth. On that basis, it was his opinion that it could not have been the cause of the initiation of the fatigue crack (T3424).

12.64. Further, Dr Powell offered the opinion that if the fatigue crack had been initiated by a thermal crack coming down from the surface of the nitrided layer, the appearance of the 'beach marks' would have been different. Photographs taken by Mr Hood (C194) and Mr McLean (Exhibit C221a), clearly demonstrate that the beach marks are of a 'bullseye' configuration, with a small circular defect at the centre, approximately 1 millimetre below the surface. If the fatigue crack had been initiated by thermal cracking, the beach marks would have been 'moon shaped or crescent shaped' coming down from the thermal crack (T3425). The striking similarity of the beach marks in the Sharp Aviation fracture (Exhibit C177f) are illustrated by the following photographs:

Mr McLean's photograph of MZK crankshaft fracture site
Exhibit C221a



Mr Hood's photograph of MZK crankshaft fracture site
Exhibit C194

Mr Murphy's photograph of JCH crankshaft fracture site
Exhibit C177f

12.65. It is noted that Dr Powell was not cross-examined by counsel for the ATSB on 11 November 2002 or when he was recalled on 12 November 2002 to give further evidence.

12.66. Mr McLean's evidence

As I have already mentioned, Mr Alasdair McLean is a post-graduate doctoral student who assisted Dr Powell. Mr McLean had also assisted Dr Zockel during the mechanical engineering aspect of the inquiry.

12.67. Mr McLean holds degrees in both Mathematics and Mechanical Engineering with Honours from the University of Adelaide, and his doctoral work is in the field of material science and stress analysis.

12.68. Mr McLean produced a PowerPoint demonstration which illustrated the angles at which cracks could be expected to be found as a result of varying causes. The diagrams (Exhibit C221) demonstrate that the actual angle at which the fatigue crack propagated is at about 75° to the angle at which thermal cracks or cracking from piston loads might be expected (see Exhibit C221 and T4384).

(Signed)

12.69. Having had the opportunity to examine these matters in detail, Mr McLean told me that he agreed with the analysis of Mr Hood, the American metallurgical engineer whose evidence I will examine in due course.

12.70. Mr McLean did not accept the ATSB's theory that abnormal bearing loads caused bearing failure resulting in the bearing rubbing on the fillet radius and causing a thermal crack, for several reasons:

- In his view the evidence suggested that the cracking occurred under reasonably low stress conditions and not in conditions where abnormal loads were being created;
- The alignment, as I have already discussed, is not consistent with a thermal crack;
- He found it difficult to believe that the bearing, having failed to the extent that it was rubbing on the fillet radius and causing a thermal crack, would then survive for between 50 and 70 flights, as the number of beach marks evident in the fracture surface demonstrate (T4386-87).

12.71. Mr McLean's opinion can be summarised as follows:

> 'It's my belief that the only reasonable explanation for a crack of that nature is a defect in the crank. The stresses associated with normal crankshaft operation do not provide a very high level of stress in that area, so to produce a crack in that area, in the absence of any other reasonable explanation, a material defect presents itself as the most likely cause for that initiating crack.' (T4389)

12.72. When cross-examined by Mr McIlwaine SC, Mr McLean agreed with Dr Powell that destructive testing of the fracture site would have been the only way of demonstrating the presence of an inclusion at the fatigue fracture initiation point (T4581).

12.73. <u>Conclusions</u>

Taking the combined evidence of Dr Powell and Mr McLean, it can be concluded that:

- There were iron oxide 'inclusions' in the sample of the material taken from the No.5 journal of the left engine crankshaft;
- The ATSB initially argued that these were not inclusions but were artefactual results of corrosion since the sample was taken. In respect of some of the abnormalities, this was advanced as merely a 'possible' explanation;

- On the balance of probabilities, I reject the ATSB's arguments, and find on the basis of Dr Powell's evidence that these were high-temperature oxide inclusions in the crankshaft material of sufficient size to materially affect the tensile and torsional strength of the crankshaft;
- The presence of inclusions in the No.5 journal gives rise to the possibility that there were similar inclusions in the No.6 journal, where the fracture occurred because, having regard to the way the crankshaft was made, it would have been in the same 'seam';
- Such an inclusion was not found at the origin of the fracture site but this does not exclude the possibility that it was lost during the fracture process;
- The nature and physical features of the fatigue crack in the left engine crankshaft are indicative of a subsurface defect in the crankshaft material.

12.74. <u>The Braly Review</u>

In late December 2001, Mr George Braly wrote a very detailed review of the final ATSB report. Mr Braly's review is Exhibit C196a. While in the United States of America, I heard evidence from Mr Braly at his engine test facility at Ada, Oklahoma.

12.75. Mr Braly has been flying aeroplanes since 1966 when he was in high school. He graduated in Aerospace Engineering from Brown University, Providence, Rhode Island in 1970. He has been qualified as a commercial pilot and a flight instructor both with single and multi engine aircraft since 1968. He is also a qualified lawyer and has a legal practice in Ada as well. Since the early 1990's, he has established an aeronautical engineering business also based in Ada Oklahoma, called General Aviation Modifications Inc, or GAMI, which produces a patented fuel injector, which is used widely in aviation. He also has a business called Tornado Alley Turbo Inc, which engineers and installs turbochargers on aircraft, and he is in the process of developing an electronic ignition system for aircraft. In order to develop the electronic ignition system, it was necessary to build an engine test facility so that the parameters of aircraft engines could be measured accurately. He described the facility as follows:

> 'It is generally regarded by those who are knowledgeable in the area that have seen it, been around it, watched it operate and understand it, it is probably the most advanced aircraft piston engine test facility that is available. It exceeds the capabilities of what the FAA can do in their engine test facility in Atlantic City, New Jersey, and we have been using that facility for research and development now for about three years.' (T3126)

(Signed)

12.76. One of the engines at Mr Braly's facility is a Textron Lycoming TIO-540J2BD engine, 'virtually identical' to the engine in MZK. The engine is mounted on a test stand and is connected to an array of instruments which monitor its performance under various conditions. Included in the instrumentation is 'modern fiber-optic in-cylinder combustion gas pressure transducers' which can precisely measure conditions within the cylinder of the engine while it is operating.

12.77. Mr Braly read the final ATSB report, Exhibit C97, and corresponded with the ATSB advising them that he disagreed with a number of the conclusions they had reached. This led to some correspondence between Mr Braly and the ATSB, including his initial commentary on the final report, which is Exhibit C196a, the ATSB reply to that commentary, Mr Braly's response to that and some further correspondence. These documents are marked Exhibits C196b, C196c, C196d and C196e respectively. He provided a report dated 21 October 2002 which was prepared at the request of Mr Kernahan, and which is Exhibit C196f.

12.78. The Executive Summary of Mr Braly's eight page report is as follows:

> '1. For absolute best longevity, the Chieftain engine should be operated full rich for takeoff, very rich for cruise-climb, and lean-of-peak for cruise and descent. Whyalla's routine operational error, codified in their OPS Specification, was operating the engine too lean during cruise-climb, ***not*** in operating too lean during cruise. However, this practice, described in their Ops Spec, was not, itself, the immediate cause of either the failed left or right engine.
>
> 2. The routine use of the inappropriately lean cruise climb mixture setting may have led the pilot of VH-MZK to complacency about the mixture setting when the pilot increased the power (manifold pressure) on the remaining right engine after the left engine crankshaft failed for mechanical reasons.
>
> 3. It is most likely the pilot of VH-MZK used a combination of high MP, 2400 RPM and an inappropriately low fuel flow (mixture) setting, on the remaining right hand engine, after the failure of the crankshaft on the left engine. This ill-advised combination of high MP, low RPM, and too low fuel flow, is fully competent to routinely cause the destruction of one or more cylinders within the short 10-13 minute operating window that existed after the failure of the left engine.
>
> 4. Cylinder deposit formation is focused on in the ATSB report as having some special role in this accident. This is highly unlikely. Deposit formation is a function of richer-than-stoichiometric mixture settings. This is a positive dose-response relationship to rich mixtures. The richer the mixture (richer than chemically stoichiometric) the more deposits form. Mixtures that are near stoichiometric or leaner, produce minimal deposits. There is no evidence that leaning causes accelerated deposit formation. On the contrary. The pistons in the failed cylinders

appear from the photographs to have had lower-than-average deposit formation, and so in all likelihood, deposit formation had nothing to do with the failures. The referenced "lead oxybromide" type deposits all melt in the range of 900°F to 1300°F. The routine 1600°F exhaust temperatures (actually, more than 3000°F for short periods of time in the combustion event) will scavange most of these deposits in routine operation.

5. The typical primary ingredients for detonation on the TIO-540J2B engine are high peak internal combustion chamber pressures (>900PSI) and high cylinder head temperatures (> 400F). Large variations in charge air temperature also affect detonation margins. Peak combustion chamber pressure is a function of manifold pressure, magneto timing, and mixture. If MP, RPM, and spark timing are held constant, maximum combustion chamber pressure (and therefore minimum detonation margin) occurs at or near best power mixture (50°F to 100°F rich of peak EGT/TIT) and mixtures substantially richer or leaner than that reduce the likelihood of detonation. The failure of investigators to verify (or report the results, if verified) magneto timing on the accident engines was a major omission.
6. The focus on mixture induced variations in fuel/air charge temperature as a cause of unusual deposit formation and subsequent related pre-ignition is a red herring. As noted, leaner mixtures, in general, produce less deposit formation. Further, the relatively small change in charge air temperature accomplished by varying the mixture from best power mixture to near best economy mixture settings is far down on the list of issues affecting detonation.
7. The most important safety recommendation that should have been forthcoming from this investigation was overlooked entirely. These aircraft used in revenue passenger service should have available state of the art multi-probe CHT & EGT engine monitors installed and the crews should be trained to properly interpret the information displayed and stored in memory. These devices would likely also greatly assist future similar post-accident investigations.' (Exhibit C196a p2-3)

12.79. Mr Braly particularly disputes the assertion that deposit-formation on the pistons led to detonation, and drew attention to the fact that, as I have already identified, this is a function of the engine running rich, not lean. He said that the debate about deposits causing detonation was a 'red herring' (Exhibit C196a).

12.80. Mr Braly outlined his opinions about the sequence of events leading to the ditching as follows:

'The following is a short summary of the sequence of events that, based on known hard engine operating data and the known objective findings surrounding the fatal crash, is what most likely happened in connection with this fatal crash:

1) The left engine crankshaft failed. The cause appears most likely to be related to improper installation of the connecting rod on the number six cylinder.

2) The pilot feathered the left engine and increased the manifold pressure on the remaining right hand engine from a normal 30” to some larger value in the 34 to 40” MP range. The pilot most likely failed to also increase the mixture on that engine to a suitably rich mixture.

3) The indicated airspeed (IAS) of the aircraft was reduced due to the left engine being feathered and the loss of nearly 50% of the previous available cruise power. The combination of the lowered cruise speed and the increased power on the right engine left the right engine in an environment very similar to a “climb condition”. That is, the engine was enjoying minimal cooling air flow due to the reduced cruise speed and suffering from higher than normal power settings, both of which are typical of operating conditions encountered during routine climbs.

4) The crucial operational error was the likely failure of the pilot fully (or adequately) to increase the mixture on the right hand engine during this engine out cruise condition. Had the pilot simply and properly increased the mixture during this critical phase of the flight, as normal training and good engine operating practices would dictate, the right engine would not have failed and the aircraft would have, more likely than not, continued to a safe landing at Whyalla.

5) Something as simple as a small excess overhang of a helicoil tang at one of the spark plugs in cylinder 6 of the right engine could have dramatically increased the susceptibility of that cylinder to pre-ignition. The photographs in the ATSB report do not detail this area of the cylinders in sufficient detail to evaluate this not uncommon cause of pre-ignition.

6) One can readily demonstrate that even a newly built or overhauled TIO-540J2B engine, in perfect mechanical condition will, under the conditions described in paragraphs 2-4 above, operate in light to medium detonation and if left unresolved, that light to medium detonation will steadily raise the cylinder head temperature to the point that pre-ignition begins. After the pre-ignition begins, the engine will suffer catastrophic failure, usually within a matter of one to five minutes, unless the pre-ignition is promptly corrected. The author of these comments invites an appropriate representative of the ATSB to visit the author’s test facility and to observe the operation of the TIO-540J2B engine in any combination of power and mixture settings desired, in order to verify each and every observation about the operation of that engine described in these comments.

7) Notes:

   a) The various different cruise mixture settings used by Whyalla and the other operators of these engines described in the ATSB report had no effect what so ever on this crash. At the reported normal cruise power settings, it is virtually impossible to cause one of these engines to detonate or pre-ignite, if the engine and the associated ignition system are in proper operating condition.

   b) The climb mixture settings used by Whyalla (as distinguished from the descriptions of the power and mixture settings used by all other operators surveyed by the ATSB) were highly improper and likely caused one or more cylinders on both engines to frequently operate in light or medium detonation during portions of each climb.

(Signed)

c) The description of "deposits" on the pistons set forth in some detail in the report is essentially unrelated to any aspect of the cause of this crash. This extended pursuit of this subject is largely a red herring. For example, the deposits such as are described and displayed in the limited photographs in the ATSB report appear, from those photographs, in actuality, to be rather more accurately described as minimal as compared to most engines with similar operating time. In fact, they generally appear to be so minimal as to support the notion that the Whyalla engines were, in fact, frequently operating for short periods of time (probably during climbs, given the reported Whyalla engine operating technique during the climb phase of flight) in light to moderate detonation and this periodic condition actually cleaned the piston domes of some of the otherwise normal deposits. A better collection of photographs of the pistons and cylinder domes would provide still more accurate information on this subject.

d) In common pilot & mechanic operating terminology, when one "leans" the mixture, one reduces the ratio of fuel to air via use of the mixture control. However, when one thus "leans" the mixture to a condition that most pilots and mechanics would routinely call a "lean" mixture, the mixture remains a stoichiometric ***rich*** mixture. (The mixture is chemically a rich mixture until the exhaust gas temperature - - as indicated by the turbine inlet temperature gage [sic] during gradual reductions in fuel flow, - - has reached a maximum value and started to decline.) The confusing terminology in this area is responsible for an enormous misunderstanding in the pilot and mechanic community of the true implications of chemically rich and lean mixtures with respect to the operation of high powered piston aircraft engines. At one point, the ATSB report on this crash attempts to accurately define these terms, but then, in other areas, fails to accurately apply the correct terminology to the operation of the engines in question, and thus, compounds the confusion for pilots and mechanics who may read the report.

In its criticism of the routine use of so called "lean" mixtures, the ATSB fell into the common trap of mis-characterising stoichiometric "rich" mixtures as being "lean" mixtures. Worse, the lay press has grabbed onto this aspect of the report and has compounded the confusion in this area with published reports that completely mischaracterize the issue, blaming the crash on the use of "lean" mixtures, with an express or implied suggestion that the airline operators of this type aircraft were trying to skimp on fuel in order to save money at the expense of operating safety. (C196a, p4-6)

12.81. Mr Braly later reconsidered a number of these conclusions. In a further report dated 12 October 2002, he said:

'At the time those matters were first considered, I had accepted at face value several of the assertions of fact and related conclusions in the ATSB report and was also unaware of certain other critical data that later came to my attention. Also, during an early portion of that time frame, the significance of the current Lycoming crankshaft Airworthiness Directive covering the relevant period of time during which the left engine

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on MZK was manufactured by Lycoming was not then apparent to me. In my earlier remarks, I concluded by soliciting comments or criticism relating to my views, and, in particular, such comments or criticism that included useful data or references which may enhance or change of the opinions expressed or conclusions reached.

There has been further information and data that has come to light since that time and I have had the opportunity to reflect further on the events surrounding the crash of VH-MZK.' (Exhibit C196f, p1)

12.82. Mr Braly explained detonation as follows:

'When the spark goes off, if everything works right, it starts a flame front, which starts to expand and move across the cylinder…..it starts to build pressure in the cylinder….and at the same time the piston is moving up the pressure is getting still larger…..The flame front is giving off infrared energy…..theoretically and ideally all of the fuel and air in this area above the piston is all homogenous and perfectly uniform….The truth of the matter is it never is - there are always significant variations. So you can have remote pockets of fuel and air in there that have different (ratios)…..If the pressure and temperature get high enough and the fuel-air ratio happens to be exactly right in this little remote pocket of fuel and air, it will auto ignite before the flame front ever gets to it and, when it does, it essentially explodes instead of burning…..and when it does, you measure a spike in the pressure…….and the spikes can go up to 1100, 1200, 1300, 1400 psi and they may be higher than that because they may happen so fast that we are unable to measure them at those higher levels.

As those spikes go up, the local temperature associated with those spikes also goes up….when this thing explodes, it starts a shock wave that rattles around back and forth inside the cylinder at the speed of sound,…..and in a 5-and-a-quarter inch cylinder it will tend to bounce back and forth about 4200, 4300 times per second, which is very much faster than the flame fronts or the burn rate, or any of that sort of thing…..

It has the following sort of deleterious effect. If you look at the cylinder and you say how hot is the combustion gas and you say it's up here around 4000 degrees or so, or 3500 to 4000,….and you look at the cylinder wall and it's only a few hundred degrees - 500, 600 or 800, 400, or whatever it happens to be, depending on how well it's cooled, at some point there has to be a transition between the very hot gas and the temperature in the wall and those kinds of transitions are called a thermal boundary layer. You have here a very small thermal boundary layer which is maybe a couple of millimetres thick.

…..the shock waves interfere with the orderliness of the thermal boundary layer - a term I use is they scrub the thermal boundary layer a bit - and in the process they allow a much higher rate of transfer of heat from the combustion gases into the cylinder head.

Therefore, when this detonation event starts, the cylinder head, all of the things remaining the same, will get hotter - the rate of heat transfer will go up into the cylinder….

An engine can operate with light detonation almost indefinitely and, in particular, it can do so if the cylinder heads don't run away with cylinder head temperature. An engine can operate in even what is defined as moderate detonation for extended periods of time, provided again the cylinder head temperatures don't run away. By the time you get to

(Signed)

very heavy detonation, it's almost a moot point, because it's impossible to keep the cylinder head temperatures from running away from you. In that situation the cylinder heads are going to get really hot……

Then some really bad things start to happen……..as the cylinder head gets hot, there are other things inside the cylinder that can get hot with it. Among the most critical of those things are the spark plug or the spark plug ceramic. The spark plugs are inserted with helicoil and sometimes there can be a small helicoil tang. There can be a sharp edge from a machining imperfection inside the cylinder; there can be an edge on an exhaust valve that is too sharp and was not properly machined - a number of things in there can get too hot from this process - we are talking about up in the 1600 degree range - and when they get that hot then we get an entirely different event……

….as the piston starts up and some time long before the spark event - long before the spark ever starts, one of these remote pockets of fuel is now hot enough, or, worse, the spark plug ceramic is hot enough to the point that it can cause the combustion event to start…..well in advance of the normal spark timing…..It can go to 1500, 1800, 2000 psi. It happens very close to top dead centre, and it is associated with extremely high temperatures and pressures, and that event is called pre-ignition…….

But it's not the only thing that can cause pre-ignition. Pre-ignition can happen just because a spark plug ceramic got too hot. If the spark plug ceramic debonds a little bit, or there's some manufacturing variation in tolerance, this can happen - a helicoil tang can happen. There are a number of things that can cause a pure pre-ignition event to happen.

They generally don't happen until the engine is under very high power and they generally don't happen unless you've got very high peak pressures that are naturally providing very high temperatures to heat everything up…….' (T3136-3141)

12.83. Mr Braly pointed out that if the engine ignition timing is inappropriately early or advanced, it would make the cylinder head temperatures rise, and the exhaust gas temperatures fall. Examining the trend monitoring data for MZK, in the period from 13 February to 9 March 2000, after the left engine was returned to service following the Maitland incident, he described:

'A very clear discrepancy between the cylinder head temperature on the left engine and right engine, and there's a corresponding discrepancy between the exhaust gas temperature on the left engine and the right engine. When you look at the data on an apples to apples comparison and pick those Powerpoints that are in the trend data that correspond to the same fuel flow so you don't have another variable in there, ……and carefully look at the data what it suggests is that during the maintenance check on 9 May (March), which included what I see in the appendix to the report a timing check, that somebody corrected a timing problem with the left engine and thereafter the cylinder head temperature and exhaust gas temperature between the left and right engine became roughly nominal (normal) with respect to each other.' (T3142-43)

(Signed)

I have already set out the relevant Trend Monitoring Data which illustrates Mr Braly's contention in paragraph 5.30.

12.84. Mr Braly rejected the idea proposed by the ATSB that the fuel mixture settings adopted by Whyalla Airlines during the cruise phase of flight were harmful to the engine. He said that the engine settings of around 28-30 inches of manifold pressure, 2,200 RPM, and using 11 or 12 gallons of fuel per hour would produce peak cylinder pressures of only around 400 psi. He said that this would produce 'an extremely benign combustion event - probably the most benign cruise operating environment of any of the reports of cruise power condition contained anywhere in the survey that was conducted and included in the ATSB report' (T3143).

12.85. On the other hand, the settings used by Whyalla Airlines during climb, which was not an area examined by the ATSB, were a different story. Using 36 inches of manifold pressure, 2,400 RPM, and 27 gallons per hour to a maximum of 1500°F EGT will produce a very high peak combustion pressure, peak temperature and exhaust gas temperature which are likely to be harmful to an engine (T3144). He said:

> 'This mixture setting for climb operations, especially if referenced to the 1,500°F EGT (actually, TIT) value is an "engine operating technique" that, based on observed engine test stand operation of the same engine, is likely to result in episodes of at least light or moderate detonation during some climbs on at least some cylinders. The use of a maximum EGT (TIT) setting as a method for setting mixture during a climb is an excellent technique that is reliable in a wide variety of ambient conditions. However, one has to find the correct value for the EGT (TIT) and a value of 1500°F is one that is clearly too high for the climb phase of flight with this engine. A value similar to that adopted by operators number 2 and 7 (1,350°F) is a value that engine test standing operating data supports as being conservative with respect to the internal values of peak cylinder pressures and the associated issue of detonation.' (Exhibit C196a, p19-20)

12.86. Mr Braly gave a PowerPoint demonstration of an actual event in which a cylinder in a similar engine was damaged, comparable with what happened to the No.6 cylinder on the right engine of MZK. Mr Braly was able to do this with the use of engine monitoring data which had been stored in the memory chip of an electronic engine monitoring system, which uses multiple probes to the engine, and which provides readouts for cylinder head temperatures for each individual cylinder, exhaust gas (or turbine inlet) temperature, fuel flow, air temperature and other important parameters.

12.87. The engine involved suffered an event due to preignition, which Mr Braly thought was probably due to a faulty spark plug. The cylinder was substantially damaged in a little over two minutes. In an aircraft which is not fitted with one of these sophisticated digital instruments, such an event could easily have passed unnoticed by the pilot (T3160-3173).

12.88. Mr Braly demonstrated by running an identical engine to those installed in MZK, and monitoring the entire range of its engine parameters which were displayed digitally on a computer screen, the effects of running the engine in various conditions. This demonstration elicited an enormous amount of very useful information which included:

- When the engine was operated at the settings prescribed by Whyalla Airlines for takeoff and climb, namely 36 inches of manifold pressure, 2,400 RPM, fuel flow 27 gallons per hour to a maximum of 1500°F EGT, the peak cylinder pressures had increased to the 900 to 950 psi range. Even though the cylinder head temperature had not increased greatly, and the exhaust gas temperature had not reached the maximum of 1500°F, the engine was in the very early stages of detonation (T3185-86).
- When the fuel flow was increased to 30 gallons per hour, the cylinder head temperature cooled considerably, the EGT was down to 1329°F, and the peak cylinder pressures were comfortably below 900 psi (T3189).
- As the timing of the engine was advanced by as little as three degrees (which Mr Braly was able to do because the engine is fitted with an electronic ignition system), the peak cylinder pressures rose to over 1000 psi, which he described as harmful to the engine (T3192). The cylinder head temperatures also rose as a result of the advanced timing. During this phase, the engine was experiencing light detonation in two of the six cylinders (T3192). Mr Braly suggested that whenever peak cylinder pressures exceeded about 1000 psi, the load placed on bearings, valves, valve seats, spark plugs, spark plug seals, rings, etc can lead to adverse effects (T3190).
- During cruise conditions, when the engine was operating at 50 degrees or more lean of peak, readouts demonstrated that this was ‘absolutely benign’ for the engine. Mr Braly said that all of the fuel is consumed, there would be minimal

(Signed)

deposits accumulated, and stresses on the mechanical components are absolutely minimal (T3198-99).

- When the mixture setting was changed to 50 degrees rich of peak, an increase in the cylinder head temperature of at least 50°F was noted. It is not until the mixture is enrichened even further that the cylinder head temperatures drop again (T3201-02).

12.89. <u>Mr Braly's comments on the ATSB report</u>

Mr Braly was highly sceptical that the crankshaft in the left engine in MZK fractured at around 1838 on 31 May 2000, and remained 'dogged together' such that the aircraft maintained performance until 1847:15. He said that the torque or torsional forces on the crankshaft would have been so enormous that it would have been 'virtually impossible' (T3212).

12.90. Mr Braly also disagreed with the ATSB contention that the left engine failed at 1847 and that, thereafter, the aircraft was able to maintain 147 knots true airspeed on the right engine alone. The ATSB asserted that to achieve this performance would require the right engine to produce 375 brake horsepower (bhp). Mr Braly said that the engine was not capable of doing so. His estimate was the engine would produce no more than about 315bhp, assuming that the density controller on the turbocharger was appropriately set (T3217).

12.91. His belief was that at 1847:15 the right engine had been throttled back so that it was producing 105 to 115bhp, and the left engine was still producing the bulk of the power (T3217-18).

12.92. Mr Braly pointed out that the operation of the density controller is temperature related, so that on a cold day it will allow only 42.5 to 43 inches of manifold pressure to be produced, whereas on a very hot day, with ambient temperatures of 110-120°F, it will allow the turbocharger to produce up to 46.5 or 47 inches of manifold pressure. Of course, on the night of 31 May 2000, when MZK was flying at 6,000 feet, the temperature was close to zero, so the density controller would only have been producing at the lower end of that range (T3220-21).

12.93. 1847:15

As to the events at 1847:15, Mr Braly said:

> 'At the point where the aeroplane diverged right on page 3 at 1847:15, I think the pilot had been wrestling with problems with the right engine since some point in the climb. I believe at about that time he decided to simply throttle the engine. He could do that, and it's my opinion that at that point in time he had experienced an episode of pre-ignition on the right engine. Whether or not it had already put a hole in the piston is debatable, but he did not, unlike the gentleman that was shown in the recreation of the data yesterday, the benefit of that sort of instrumentation and he would not have likely been able to stop the event before it did damage to the cylinder and, as indicated yesterday, once that sort of thing starts to happen in the cylinder, even if he throttled the engine, if you later reapply power, it's going to happen again, assuming he had a hole in the piston already.
>
> It is my opinion that the pilot decided simply to throttle the right engine and, in the process of that, the aeroplane yawed to the right slightly. In my experience teaching multi-engine pilots to fly during training, a momentary lapse in the heading control of the aircraft during major left/right power discrepancies is more common than not, even among good pilots, and I think the right-hand turn data is consistent with that, and a prompt re-correction back on course is consistent with him having done that and then retrimmed the aeroplane by use of the rudder trim control and what not to put the aeroplane back on course.
>
> At that point in time the pilot had an unknown problem with the right engine, but it was still operating, and he had a 250- or 260-hour left-hand engine, and he made the decision to continue on. In the process he would have likely pushed up the power on the left-hand engine to something approaching climb power. He may have in fact used climb power - that would be a common training scenario for a multi-engine pilot, that if you lose an engine, you put the other engine up to climb power. That's not necessarily the most optimal training exercise, but it's a common method of teaching multi-engine pilots.
>
> So I believe he increased the power on the left engine as he reduced the power on the right engine, and pressed on.
>
> Some time just before 1901:10 when the MAYDAY was transmitted I think the crankshaft failed on the left engine. When the aircraft hit the water the left engine was feathered - I think the left engine would have virtually auto-feathered from the oil pressure loss. The right engine was still turning and not feathered, which is consistent with the previous power reduction.
>
> I think if he had not already had a hole in the piston at the time - 1847:15 - when he throttled that engine, or when he tried to power up the right engine after the failure of the left, that he would have holed it promptly, because it would have gone back into pre-ignition.
>
> It would have been a very confusing and difficult situation for the pilot. They simply do not train for simultaneous engine failures, and they certainly do not do it at night with a full load of passengers over water.' (T3221-23)

(Signed)

12.94. Mr Braly conceded that it is possible that Mr Mackiewicz had completely feathered the right engine, rather than throttling it back, and then unfeathered it after the left engine crankshaft failed, so that it was operating shortly before the aircraft hit the water. He said that he thought it was 'almost unthinkable' that Mr Mackiewicz would have done that without making a PAN call (T3223).

12.95. Airspeed after 1847

Mr Braly provided me with a further report dated 14 November 2002 (Exhibit C196m) addressing the issue of whether MZK was capable of maintaining a true airspeed of 147 knots on one engine, as postulated by the ATSB. Mr Braly examined the possibilities by making a test flight in a similar but not identical aircraft being flown at 6,000 feet and shutting down the right engine and observing the airspeed of the aircraft and reporting same on videotape.

12.96. Mr Braly reported that flying the aircraft at 2,400 RPM, with a manifold pressure of 40 inches resulted in an indicated airspeed of 130-131 knots, which converted to a true airspeed (TAS) of approximately 144 knots. Allowing for the fact that the test aircraft was 350 pounds lighter, and was equipped with intercoolers on both engines and 'winglets', whereas MZK was not, Mr Braly expressed the opinion that MZK would not have been capable of producing more than 140 knots TAS on the night of 31 May 2000. He said:

> 'At the observed 2400 RPM, the engine would have been capable, at 43" of MP, of delivering only approximately 326 BHp. At 45" it would produce no more than about 335 to 340BHp - - and none of these power outputs would be anywhere sufficient to produce the claimed speed of 149KTAS asserted and described in the ATSB report.'
>
> (Exhibit C196m, p3)

12.97. Lead Oxybromides

Mr Braly was critical of the ATSB's conclusions in relation to the presence of lead oxybromides and their alleged role in the failure of the two engines in MZK. In particular, at page 52 of Exhibit C97 there is reproduced, from an American website, a picture of the piston of an engine which failed in what is known as the 'Sacramento Sky Ranch' incident, and which was used by the ATSB as an example of abnormal engine deposits. The caption to figure 24 on that page reads as follows:

> 'Combustion deposits associated with detonation/preignition resulting from the combustion of aviation gasoline contaminated with aviation turbine fuel (Sacramento Sky Ranch)' (Exhibit C97, p52)

(Signed)

12.98. Mr Braly said that that photograph was depicted in the ATSB report as an example of piston damage from abnormal combustion events. The swirl-patterned deposits on the top of the piston are described on the website as 'normal'. He described the use of the picture to demonstrate abnormal deposits as 'intellectually dishonest' (T3229).

12.99. As to the identification of lead oxybromides as an issue in this case, Mr Braly said:

> 'In the world of medicine, for example, when one is considering all the possible causes of some injury, there is a saying that is used in the medical schools - you need to put yourself in the middle of the plains of North America to appreciate this - that if you hear a herd of hooves coming up behind you, you need to think horses or cattle but not zebra. You need to look at those things that are most highly likely long before you start to consider African zebra running across the Plains of Oklahoma or Kansas. It appears to me that the focus of the ATSB report immediately jumped to the zebras instead of looking for cattle or horses, or even extinct buffalo, as the primary cause of all the bad things that happened on the night of 31 May.' (T3232)

He said that the floating of this issue has caused considerable confusion in the aviation community. He said:

> '….as the principal focus and the cause of this kind of an accident in the face of the accumulated experience to the contrary for the last 60 years, it was entirely inappropriate and misdirected - and, worse, the suggestions of it were prominently published and disseminated with equally uninformed advice to the pilot aviation community, which ended up playing a major role in perpetuating and reinforcing a whole host of what are referred to in the aviation community as old wives' tales about engine operation that are simply erroneous and was therefore a considerable disservice to the pilot and mechanical community.' (T3234)

12.100. From the photographs of the six pistons from the right engine of MZK appearing on pages 50 and 51 of Exhibit C97, Mr Braly described the deposits as 'minimal' (T3235). In one of his reports, Mr Braly said:

> 'It is my further opinion that lead oxybromide deposits in each engine were normal or even minimal, as compared to countless other engines with more or less operating time, and played absolutely no role whatsoever in the failure of the crankshaft.'
>
> (Exhibit C196f, p3)

12.101. Failure sequence

In cross-examination by Mr McIlwaine SC, Mr Braly said that the three reasons why he holds the opinion that the left engine did not fail first at 1847:15 were:

- 'It is unlikely that the aircraft would have been able to maintain a true airspeed of 147 knots on one engine;
- It is almost inconceivable that if Mr Mackiewicz had suffered a catastrophic failure of the left engine at that point, resulting in feathering of the propeller, he would not have reported an emergency over the radio;
- The turn to the right is 'several times more likely' to be the result of the reduction of power output of the right engine rather than failure of the left.' (T3279-81)

12.102. Mr Braly outlined his view on the cause of the left engine crankshaft failure in his final report as follows:

> 'It is my further opinion that the crankshaft on the left engine of MZK would not have broken on the night of May 31, 2000, but for the operating conditions under which the engine suffered from February 13, 2000 until March 9, 2000. A review of the trend data for that period of time indicates that the left engine was returned to service on February 13 (see Table 1, below) with the timing advanced (sparks too early) by a substantial and harmful amount. There is no other competent cause for the left engine CHTs to be so exceptionally hot (+62.5 degrees F) compared to the right engine and, at the same time, the left engine EGTs to be so cold (-76 degrees F) compared to the right engine, than an error in setting the timing on the left engine too early in the Feb. 13 to March 9 time frame - - and to show resolution of those substantial differences immediately after the March 9th maintenance event. The intolerable insult that this condition imposes on the engine can be demonstrated for the Coroner on the engine test stand. The crankshaft in question suffered the initiation of a fatigue crack. That crack continued to grow until the static strength of the remaining material in the crankshaft was no longer able to sustain the peak torsional loading imposed by the engine combustion events. Had the crankshaft not suffered from the insults resulting from the improper February 13 to March 9 operation of the engine, the crankshaft may have still broken at some later date, but, more likely than not, such failure would have happened at some time after May 31, 2000.' (Exhibit C196f, p3)

12.103. Conclusions

The evidence of Mr Braly leads to the following conclusions:

- Even if Whyalla Airlines was using lean fuel mixtures in the cruise phase of flight, this would have led to 'benign' and not abnormal combustion events in the engine, and fewer deposits. The discussion of lead oxybromides is a 'red herring';

- The mixture settings used by Whyalla Airlines in the climb phase would probably have led to detonation which would have been exacerbated by the advancement of the engine timing in February and March 2000 as evidenced by the trend monitoring data;
- This abnormal combustion may have initiated or exacerbated this fatigue cracking of the left engine crankshaft;
- It is highly unlikely that the left engine failed completely, and suddenly, at 1847:15 because the right engine alone was not capable of producing enough power to propel the aircraft at the speeds indicated;
- The yaw to the right was more consistent with partial reduction of power from the right engine, and Mr Mackiewicz would have made a Pan call.

12.104. Investigations by McSwain Engineering Inc.

At the request of Mr Greenwell, counsel for the relatives of the deceased, and with the support of Counsel Assisting and CASA, the components of both engines from MZK were shipped to the United States of America where they were examined by Mr Mark Hood, an engineer employed by McSwain Engineering Inc.

12.105. Mr Hood is a Metallurgical Engineer registered in the State of Florida and has been employed by McSwain Engineering Inc. since 1995, engaged in non-destructive testing and failure analysis particularly in accident related cases. He is a member of the American Society of Metals International Failure Analysis Committee.

12.106. The examination took place in September 2002 at the premises of R J Lee Inc. in Pittsburgh, Pennsylvania, and representatives of Textron Lycoming were present at the examination. Included in the components examined were the bakelite-mounted sample from the No.5 main bearing journal of the left engine which had been analysed by Dr Powell as described above. During the course of Dr Powell's examination the sample had been sectioned into two pieces and mounted separately.

12.107. The costs of shipping of the components to the USA, and the analysis by McSwain Engineering Inc, were met by the lawyers representing the families of the deceased. It was well known by all who participated in the inquest that there was litigation in progress in the United States of America between the relatives of the deceased and

Textron Lycoming and between Whyalla Airlines Pty Ltd and Textron Lycoming, and that the testing would have relevance both to that litigation and to my inquiries.

12.108. The stated purpose of these arrangements was to carry out the 'destructive testing' for the purpose of attempting to determine definitively whether there was an inclusion at the initiation point of the fatigue fracture or not. As each of the experts pointed out, the only way this could be done was to section the metal fragments on either side of the fracture and progressively grind, polish and microscopically examine each side to the point of, and then past the initiation point of the fracture, to the extent that the sample is destroyed.

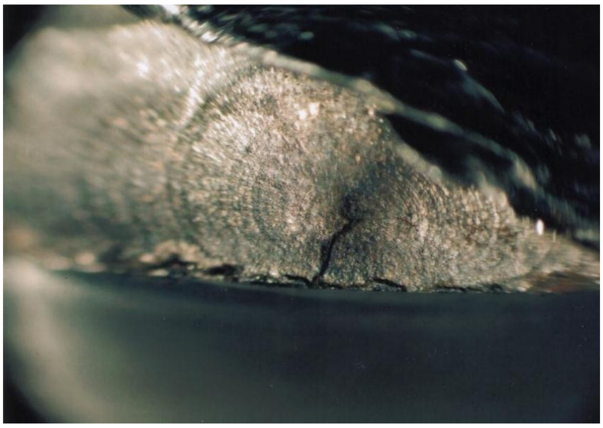
12.109. Mr Kernahan wrote to the solicitor for the relatives, Mr Michael Prescott, on 8 October 2002. Mr Prescott was acting as the conduit between my inquiry and McSwain Engineering Inc in the United States of America. Mr Kernahan, on my instructions, specifically authorised destructive testing. At page 5, he wrote:

> 'The appropriate experts are authorised to carry out such testing including the interference with the integrity of the exhibits, provided the same is documented and photographed, in order to provide the opinions sought by this request including cutting of sections from any of the engine parts and applying appropriate materials to remove rust and/or other contaminants which interfere with the analysis that we seek.'

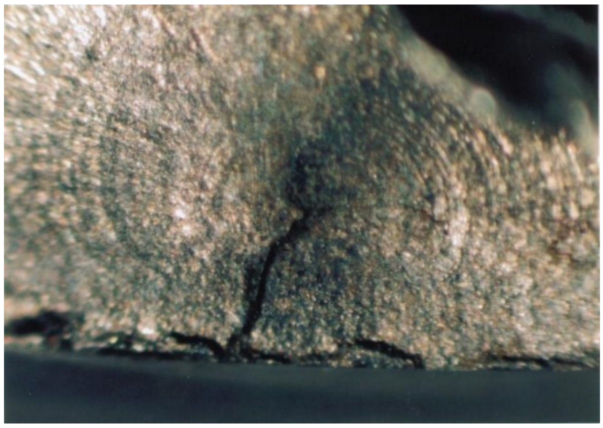
12.110. Disappointingly, it was ascertained after our arrival in the United States of America, and shortly before the hearing in New York, that this destructive testing had not been undertaken and that a definitive answer to these questions had not yet been obtained.

12.111. Evidence was taken in New York from Mr Hood on 23 October 2002. Mr Hood told me that he photographed the crankshaft, both without magnification and through a stereo microscope. The section of the fracture was also examined under a scanning electron microscope (SEM).

12.112. The SEM photographs (marked A and B in enclosure 3 to Mr Hood's report, Exhibit C194), clearly demonstrated the concentric beach mark rings emanating from a point which Mr Hood described as approximately a millimetre below the surface as well as what he described as a 'tear ridge' emanating from the fracture origin to the surface (T2961). These photographs which so clearly demonstrate the beach marks and the tear ridge are reproduced on the following page:



A



B

12.113. Mr Hood said that it was his opinion that the origin of the fatigue failure in the crankshaft of the left engine of MZK was the point demonstrated as being at the centre of the beach marks in the photographs reproduced above, which was ‘subsurface’. He specifically rejected the suggestion that the crankshaft failure was initiated by a heat related crack in the nitrided surface, as suggested by Dr Romeyn and the ATSB (T2963). Using photograph B above, Mr Hood explained:

> 'For a surface-initiated fatigue, it will propagate typically in an arc, or as the crack front moves out. These bands or arcs are indicating the crack front propagation. When you see these arcs circle back around behind and create basically a bull’s-eye-type effect, that is indicating that there is a point origin some place subsurface, and if you follow the rings back to the centre you get back to the origin area, which is basically in this area right here (indicates).
>
> This line right here is a tear ridge, because as the fatigue progresses from this point of origin, it initiates and propagates on separate planes and, as the crack grows to the surface on two uneven planes, once you get to where you can no longer sustain the load with the ligament or the small section of material that is between those two planes, you create this tear ridge, and that is what we can see here (indicates).'
>
> (T2963-4)

12.114. Mr Hood outlined his conclusions in his report:

> 'Based on the component evaluations performed to date, the review of literature and reports related to the subject accident, and my background and experience, I have reached the following preliminary conclusions to a reasonable degree of engineering certainty in my field:
>
> 1. The subject aircraft’s left engine was a Lycoming TIO-540-J2B with approximately 262 hours since overhaul by Textron Lycoming.

2. The subject aircraft's left engine crankshaft failed due to fatigue at the No. 6 connecting rod journal.
3. The fatigue cracking in the subject aircraft's left engine crankshaft was subsurface initiated.
4. The fatigue cracking physical evidence in the subject aircraft's left engine crankshaft is not consistent with thermal cracking.
5. The fatigue cracking physical evidence in the subject aircraft's left engine crankshaft is not consistent with a shift of the No. 6 connecting rod bearing resulting in rubbing at the crankshaft journal radius.
6. The failure of the subject aircraft's left engine No. 6 connecting rod was secondary to the failure of the crankshaft.
7. The subject aircraft's left engine crankshaft had cracking at the No. 5 connecting rod journal and the No. 3 main bearing journal that were secondary to the No. 6 main bearing journal fatigue failure.
8. The subject aircraft's left engine crankshaft exhibited a high oxide inclusion content in the No. 5 main bearing journal that is located adjacent to the failed No. 6 connecting rod journal.
9. The oxide inclusions observed in the section taken from the No.5 main bearing journal would be typical of the type of defect that would cause subsurface fatigue crack initiation.
10. The subsurface initiated fatigue cracking of the accident aircraft's left engine crankshaft No. 6 connecting rod journal was most probably due to a microstructural anomaly, such as a subsurface inclusion.
11. The subject aircraft's left engine crankshaft, S/N V537912936, is identified as having a material related issue that could result in failure by Textron Lycoming Mandatory Service Bulletin No. 553 dated September 16, 2002.

The above are my findings and opinions of this investigation to this date. Further destructive testing is required to positively identify the nature of the microstructural anomaly/inclusion at the fatigue crack origin. A protocol will be developed to complete the analysis of the crankshaft failure, as well as to answer the remaining questions surrounding the failure of the subject engines. Following further review and study, these opinions may be modified or additional opinions may be produced.'

(Exhibit C194, p4-6)

12.115. As to the oxide inclusions in the bakelite-mounted samples from the No.5 main bearing journal, Mr Hood arranged for these inclusions to be examined under SEM and x-ray energy dispersive spectroscopy (EDS), which characterised the inclusions as oxide in nature.

12.116. As I have mentioned earlier in these findings, Mr McIlwaine SC spent considerable time cross-examining Mr Hood about the peaks in the EDS spectra attributable to chlorine, and introduced for the first time in New York, the suggestion that these samples had been etched with concentrated hydrochloric acid (T2981). When we returned to Australia, this was later clarified in the evidence of Dr Romeyn and Mr Blyth. It was alleged that the samples were etched with a substance known as Marbles reagent, one of the components of which is hydrochloric acid. However, as I have already discussed in relation to Dr Powell's evidence, this issue became irrelevant after the dialogue between Dr Romeyn and Dr Powell in December 2002, as a result of which Dr Romeyn abandoned the idea that hydrochloric acid played a part in the creation of the anomalies on the surface of the sample.

12.117. Mr McIlwaine SC pressed Mr Hood for some time in cross-examination about his opinion that the planar discontinuity he identified was indeed a tear ridge, as he suggested, or whether it was a thermal crack. The debate became so technical that Mr McIlwaine SC asked Dr Romeyn to take over and ask a number of questions of Mr Hood, who remained positive that it was indeed a tear ridge (see T2992-99).

12.118. Mr Hood was also asked to examine photographs Exhibits C177b and C177f which were the photographs taken by Mr Murphy as part of his examination of the fractured crankshaft in the Sharp Aviation aircraft, VH-JCH, on 14 December 2001. I have reproduced on of those photographs in paragraph 12.64. Mr Hood agreed that the general characteristics of the two fractures were 'very, very similar' (T3015). In particular, both fractures were subsurface initiated, the fracture propagated up through the nitrided layer and down through the core of the crankshaft, and the point of initiation was similar to that in MZK (T3016).

12.119. Mr Hood pointed out that the presence or absence of oxide inclusions at the very point of initiation of the fracture may or may not be determinative. He said:

> 'When you get a separation in a fatigue crack, the inclusion can reside in one piece of the fracture. You can fracture the inclusion or it can remain on either half of the fracture, and the void may be the hole that has been left by an inclusion being separated.'
>
> (T3016-7)

12.120. The final McSwain report – destructive testing

Mr Hood wrote a further report dated 7 March 2003 following further efforts to convince those involved to carry out destructive testing of the samples, in order to answer the outstanding questions posed by the expert witnesses.

12.121. After detailed and extensive negotiations, representatives of McSwain Engineering, Textron Lycoming and the ATSB gathered at the R J Lee Inc laboratory in Pittsburgh, Pennsylvania on 13-16 January 2003, to conduct further testing. Amazingly, this session still did not culminate in the destructive testing of the samples.

12.122. Following further negotiations, the destructive testing was finally completed on 27-28 January 2003. An objection was noted from the ATSB that by this latter time their representative had left the USA. The circumstances in which this came about are complicated and indeed tiresome, but I am satisfied that there was no attempt to mislead the ATSB by waiting until after its representative had left the USA before proceeding. What in fact happened was that the representatives of McSwain and Textron Lycoming were reluctant to proceed to destructive testing, being obviously cognisant of the litigation which was still extant in America, and no doubt taking into account advice received from lawyers for the relatives of the deceased and for Textron Lycoming. It was only after my further insistence, communicated through Mr Kernahan, that the destructive testing was finally carried out.

12.123. The results of the destructive testing were set out in the final McSwain report dated 7 March 2003 as follows:

> '3.1 Left Engine Crankshaft
>
> The reconstructed failed crankshaft is shown in Enclosure 1A, and the failed No. 6 connecting rod journal fracture surfaces are depicted in Enclosure 1B. The crankshaft had been sectioned to remove the two fracture pieces during the ATSB investigation.
>
> The fracture surfaces were extensively documented using optical microscopy and scanning electron microscopy. The journal aft fracture surface origin is shown in Enclosure 2. The origin exhibited a beachmark pattern consisting of concentric rings indicative of subsurface initiation. A tear ridge, caused by the bi-planar propagation of the crack towards the surface, extended from the origin to the journal surface. The area where the tear ridge intersected the journal surface is shown in Enclosure 3. There was no indication of crack extension along the journal surface as would be expected if the ridge feature was caused by thermal cracking. No evidence of thermally-induced cracking due to connecting rod journal bearing contact was observed on the journal. The

heat discoloration noted is most likely the result of heat generated during the connecting rod failure following the crankshaft journal failure.

The forward fracture surface was similarly examined. The forward fracture surface origin area is shown in Enclosures 4 and 5. A small pocket was noted near the end of the tear ridge and was at the center of the circularly radiating crack front. Chemical analysis via energy dispersive x-ray spectra in the pocket area indicated the presence of aluminium, calcium, magnesium, and oxygen. The spectrum from the small pocket area is shown in Enclosure 6.

The forward half of the failed No. 6 connecting rod journal was selected for further sectioning to evaluate the material and microstructure at the origin area. The section was removed using a wire EDM technique. The removed cross section was mounted in a clear mounting material to permit monitoring of the serial polishing process. The mounted section was incrementally polished into the origin and evaluated after each subsequent polishing step by optical microscopy and/or scanning electron microscopy. The serial polishing resulted in evaluation of the material at ten different planes over an approximate 0.140 inch distance. No indications of large oxide inclusions or of an oxide inclusion seam were observed. However, cracking was observed in the journal radius parallel to the primary fracture plane, as shown in Enclosure 7.

The final polish plane at the origin was evaluated in detail. Small randomly dispersed round calcium-rich oxide inclusions were observed in the cross section. The inclusions measured approximately 5-10 microns. A typical inclusion and the associated x-ray energy spectrum are shown in Enclosure 8. The pocket area at the origin showed no indication of an inclusion. However, any inclusion that may have been present could have been lost during the fracture process.

Microhardness testing adjacent to the fatigue crack fracture plane revealed a near surface hardness of 52 HRC (Rockwell C) measured approximately 0.002 inch below the journal radius surface. The hardness profile tapered to a core hardness of approximately 40 Rockwell C. The reported core hardness specification was 32-37 HRC.

A section of the crankshaft material was submitted for chemical analysis. The test report is included as Enclosure 9. The crankshaft composition was consistent with the requirements of AMS 6414H, although the carbon content at 0.434% was slightly above the specified maximum of 0.43%. The LECO method was used for carbon analysis.

A section from the crankshaft was notched and impact fractured to evaluate the fracture appearance. SEM examination revealed an atypical fracture appearance, as shown in Enclosure 10. A similarly produced fracture from an older vintage Lycoming 540 crankshaft is shown in Enclosure 11. The older crankshaft material exhibited typical overload dimple rupture features.

4.0 Conclusions

After further evaluation of the failed left engine crankshaft, I have reached the following conclusions to a reasonable degree of engineering certainty in my field:

1. The subject aircraft's left engine was a Lycoming TIO-540-J2B with approximately 262 hours since overhaul by Textron Lycoming.

(Signed)

2. The subject aircraft's left engine crankshaft failed due to fatigue at the No. 6 connecting rod journal.
3. The fatigue cracking in the subject aircraft's left engine crankshaft was subsurface initiated.
4. The fatigue cracking physical evidence in the subject aircraft's left engine crankshaft is not consistent with thermal cracking.
5. The fatigue cracking physical evidence in the subject aircraft's left engine crankshaft is not consistent with a shift of the No. 6 connecting rod bearing resulting in rubbing at the crankshaft journal radius.
6. The failure of the subject aircraft's left engine No. 6 connecting rod was secondary to the failure of the crankshaft.
7. The subject aircraft's left engine crankshaft had cracking at the No. 4 and No. 5 connecting rod journals and the No. 3 main bearing journal that were secondary to the No. 6 connecting rod journal fatigue failure.
8. The laboratory-induced impact fracture from the subject crankshaft did not exhibit typical overload fracture features.
9. The failure of the accident aircraft's left engine crankshaft No. 6 connecting rod journal was due to a manufacturing related material condition that resulted in subsurface fatigue crack initiation.
10. The subject aircraft's left engine crankshaft, S/N V537912936, is identified as having a material related issue that could result in failure by Textron Lycoming Mandatory Service Bulletin No. 553 dated September 16, 2002.

Following further review and study, these opinions may be modified or additional opinions may be produced.'

12.124. Issues, Discussion and Conclusions – see Section 14

Further discussion of the issues arising from this section, and the conclusions to be drawn from them, appears in Section 14 of these findings.

13. ATSB – Response and Further Investigation

13.1. Dr Arjen Romeyn

I have already mentioned that Dr Arjen Romeyn is a Transport Safety Investigator with the ATSB and is the Team Leader -Technical Analysis. Dr Romeyn is a metallurgist with a Bachelor of Science degree with Honours from the University of New South Wales, a Master of Science degree in Metallurgy, and a PhD in Metallurgy from the University of New South Wales conferred in 1981. He is a Chartered Professional Engineer. Dr Romeyn has extensive experience in private industry, as an academic in Materials Science, and as a research scientist.

13.2. Dr Romeyn joined the Department of Aviation in 1984. That Department became the Civil Aviation Authority, and later the Civil Aviation Safety Authority, until the Bureau of Air Safety Investigation was formed in 1997, which became the Australian Transport Safety Bureau in 1999.

13.3. Dr Romeyn is a very experienced aviation accident investigator, having been involved in more than 500 investigations.

13.4. Dr Romeyn's analysis started with the same proposition as the one advanced by Mr Cavenagh, namely that the chance of independent engine failures occurring on a twin-engine aircraft, leaving aside fuel exhaustion, is "extremely remote" (T4017). Dr Romeyn said that having regard to the enormous number of hours flown in aircraft, the probability of a single engine failure is something like $1:10^{-7}$ to $1:10^{-9}$. Obviously the probability of two independent engine failures is much lower than that, and it becomes somewhat meaningless to analyse how much lower. As Dr Romeyn said:

> 'It is just how you qualify "remote". You run out of adjectives.' (T4019)

13.5. It seems to me that the ATSB's decision to limit their investigation by adopting that approach was inappropriate. The overwhelming weight of the evidence before me suggests that these two engine failures were independent of each other, and it is not enough for the ATSB to simply dismiss that conclusion on the basis that its likelihood is too remote. If that conclusion is to be dismissed, it should be dismissed on a scientific basis rather than on a statistical one. From that starting point, the

(Signed)

ATSB has set out to establish that the failure of these two engines was a dependent failure and, in doing so, has unnecessarily fettered the scope of their investigation.

13.6. Dr Romeyn disagreed with the opinions expressed by Dr Powell, Mr McLean, Mr Hood and Mr Murphy, that the fatigue crack initiated as a result of a 'point defect' approximately 1mm below the journal surface at the junction between the nitrided layer and the core of the crankshaft. He argued that Mr Hood's explanation that the discontinuity was in fact a 'tear ridge' was unlikely (T4039). Dr Romeyn conceded that there was really no evidence to confirm which of these two opposing views is the correct one (T4043).

13.7. Dr Romeyn argued that the presence of chlorine in the inclusions alleged to have been present by Dr Powell and Mr Hood was inconsistent with the inclusion having been caused by the manufacturing process, and the absence of an actual inclusion at the fracture initiation point was also inconsistent with the alternative view (T4045).

13.8. In relation to Dr Zockel's evidence, Dr Romeyn argued that it is possible to initiate and propagate fatigue cracking, alternately under both tension and compression (T4052). In effect, he did not agree with Dr Zockel's analysis that the fatigue crack propagated under tension only, which excludes abnormal combustion as a cause for the fracture of the crankshaft.

13.9. As to Professor King's evidence that the only sign of lead oxybromide in the left engine of MZK was that found by the Australian National University investigation at one point on the No.6 piston, Dr Romeyn said that his analysis of other engines over the previous two years led him to the conclusion that such oxybromides are often present. He suggested that when the big end of the connecting rod broke, the piston was projected into the cylinder head and the subsequent collision may have caused the deposits to have been dislodged from the crown of the piston (T4055). He also speculated that immersion in seawater may also have loosened those deposits (T4056). He also pointed out that any such abnormal combustion may have occurred up to 50 flights previously, and the deposits may have built up and then blown away with subsequent operation of the engine (T4057).

13.10. These arguments, it seems to me, are examples of the artificiality which can develop when an investigation tries to make the available evidence fit a theory, rather than the other way around. When faced with the opinion of Professor King and Mr Braly

(Signed)

that the amount of deposits was insignificant, Dr Romeyn was forced into speculation that there may have been more deposits but they have since disappeared. Such speculation is of little value.

13.11. Dr Romeyn said that he had been misinterpreted about the importance of this issue in his analysis. He said that he merely raised it as an issue for further investigation (T4280).

13.12. Mr Eriksen, counsel assisting me, put to Dr Romeyn the weight of evidence in favour of the proposition that the failure of the left engine crankshaft in MZK was due to a manufacturing defect. This evidence included the similarity with the Sharp Aviation crankshaft, the knowledge of 14 other failures, the American information in the FAA briefing paper already referred to, the mandatory recall of engines fitted with similar crankshafts on three separate occasions, the last of which included the left engine crankshaft of MZK. Dr Romeyn conceded that a material defect in the crankshaft, rather than thermal cracking, was a possible explanation for the failure. He said:

> 'I would certainly, on the basis of all that information, consider it as a possibility, and I guess on the basis of having that information at the time would have prompted me to examine that fatigue fracture origin more closely, and I suppose more closely as (at) the fracture surface, but the material in that location, to see if there was evidence of a material defect of that kind.' (T4275)

13.13. Dr Romeyn referred to the swirl patterns which he found on the Internet at the Sacramento Sky Ranch website, which he described as 'very similar' (T4068) to the pistons on the right engine of MZK. It will be recalled that it was this reference which Mr Braly described as 'intellectually dishonest'. Dr Romeyn explained:

> 'In the pursuit of trying to get some understanding of the nature or the reasons why the distinctive swirl patterns were present, I was mindful to look at other pistons and in doing so, searched the Internet and found on the Internet site Sacramento Sky Ranch Internet site, a photograph which depicted very similar swirl patterns. It's not my intention to make any judgment about whether that it normal or abnormal, purely to note that what appears to be a carbonaceous deposit in a swirl pattern was associated with the failure of an engine that was reported to have occurred as a result of contaminated fuel and I made the observation that if fuel was contaminated and the octane rating of that fuel reduced, that it would be likely that the detonation and rapid failure of the piston would occur more likely under high power conditions existing at takeoff into climb, under those conditions when the engine would be operated under rich mixture conditions

> as opposed to lean; and the photograph on Sacramento Sky shown in figure 24 is purely to draw the reader's attention to that and to contrast it with the deposits and the nature of the deposits present on the pistons from NPA. The issue that I was trying to get evidence for is whether there was any indication that the MZK right engine event occurred under conditions of rich or excess fuel mixtures as opposed to the leaner mixtures used in cruise. The NPA event was noted to have occurred during the cruise phase of flight and was acknowledged to be the result of exceeding temperature limitations during that part of the flight.' (T4068-69)

13.14. It is at this point that I found Dr Romeyn's evidence confusing and somewhat contradictory to the ATSB position. The theory advanced by Mr Cavenagh and his assistant Mr Fearon was that the left engine failed first at 1847, and that as a result the pilot 'firewalled' the throttle of the right engine in order to obtain maximum power, which thereby enabled the aircraft to fly at 147 knots true airspeed. In doing so, the theory suggested that the pilot, in the agony of the moment, neglected to firewall the mixture control as well, thereby creating abnormally lean mixture conditions at a high power setting, thereby leading to end gas detonation and damage to the No.6 piston of the right engine leading to its failure. This theory is quite inconsistent with Dr Romeyn's theory about the presence of carbonaceous deposits on the No.6 piston, due, as he asserts in the final ATSB report:

> 'The characteristics of the piston crown deposits remaining on the pistons of MZK's right engine indicate that detonation is likely to have occurred under rich mixture conditions. That is, the detonation free operating limits were exceeded at a high engine power setting.' (Exhibit C97, p52)

13.15. After the final destructive testing carried out by McSwain Engineering Inc in the United States of America was completed, the Executive Director of the ATSB, Mr Kym Bills issued a Notice pursuant to section 19CC of the Air Navigation Act 1920 dated 13 February 2003, directed to me. The notice required me to produce for inspection the following items:

> 'To produce the crankshaft (serial number V537912936) from the left engine of Piper PA31-350 Chieftain VH-MZK in its entirety, including any pieces or mounted specimens, currently held in the United States.'

13.16. The notice to produce carries the following warning:

> 'IMPORTANT NOTICE: Failure to comply with this notice may incur a penalty. Compliance affords protection.'

(Signed)

Indeed, section 19CC(4) of the Act creates an offence of failing to comply with such a requirement, and prescribes a penalty of '30 penalty units'.

13.17. The lawfulness of a government official, whose organisation has been given leave to appear as a party to an inquest, issuing such a notice while the inquest is still sub-judice is, in my opinion, debatable. I believe there are sound arguments based upon recent authority emanating from the High Court considering section 109 of the Constitution, which suggests that such an action may constitute an unreasonable interference with State legislative powers (see Austin v The Commonwealth of Australia [2003] HCA 3).

13.18. Leaving the legality of the notice to one side, the propriety of a party given leave to appear at an inquest using legislative powers directed at a judicial officer while a matter is still sub-judice is even more debatable. When applying for leave to appear at an inquest pursuant to section 21 of the Coroners Act 1975, a person can be taken, in my opinion, to have submitted to the jurisdiction conferred upon the Coroner by that Act. Any such party who then invokes Commonwealth statutory power, with the threat of criminal sanctions against the Coroner, who is a judicial officer in such proceedings, is behaving, in my opinion, in a completely unacceptable way. At the very least, it may have justified a reconsideration of whether leave to appear should continue.

13.19. In any event, on the 25 February 2003 I issued summonses to the relatives of the deceased persons to produce the items referred to in the section 19CC notice in an effort to secure the return of the articles in question to Australia.

13.20. The ATSB expressed the wish to conduct further testing having regard to the fact that on 21 November 2002, the Executive Director of the ATSB officially reopened their inquiry into the tragedy, not because of anything which had arisen as a result of my inquiry, but because, according to a press release issued by the Executive Director of the ATSB on that day:

> 'Ongoing delay with such testing has led to ATSB formally re-opening the investigation based on the 16 September 2002 service bulletin alone. The ATSB has also been told that some US litigation settlements require that engine parts be destroyed - such a loss of evidence would, of course, undermine the current inquest and future aviation safety. ATSB wishes to ensure that every effort is made to test the crankshaft without delay to resolve the question of whether a manufacturing material problem was a causal factor.'
>
> (Exhibit C216)

(Signed)

The 16 September 2002 service bulletin was the one which recalled crankshafts because of a material defect, and which specifically identified the left crankshaft of MZK as one of the crankshafts involved (see paragraph 10.31).

13.21. This testing should have been performed by the ATSB in 2000-2001 when they still had custody of the components. It was not enough that they assumed that because there were no defects apparent upon this inspection of the sample from the No.5 journal, and from a microscopic examination of the fracture site, that no such defect existed in the No.6 journal. Thoroughness and scientific accuracy demanded a detailed and, if necessary, destructive examination of the fracture site. I find the explanation offered by Dr Romeyn (T4083), Mr Blyth (T3876-77) and Mr Cavenagh (T3572), namely that they wished to preserve the fracture site "so that it would be available for others to examine or test", merely disingenuous and unworthy of credit. It was never made clear whom they anticipated would be testing the components subsequently. It is clear to me, from events in 2002, that it was not done for my benefit.

13.22. I also found the actions of the ATSB in this regard somewhat mystifying, having regard to the following factors:

- Dr Romeyn had conceded in cross examination that there was no evidence to confirm whether the two opposing views as to the causation of the failure of the crankshaft in the left engine was initiated by thermal cracking, as he suggested, or by a material defect in the crankshaft, as postulated by Mr Hood, Dr Powell, Mr McLean, Mr Murphy and others (T4043);
- Dr Romeyn acknowledged that if he had been aware of the opposing views which I have outlined above, he would have examined the origin of the fatigue fracture more closely, particularly at the fracture surface, when he was examining the crankshaft failure, before the engine parts were released by the Executive Director of the ATSB ostensibly to the aircraft owners, Whyalla Airlines, until that process was interrupted by the issue of a warrant for seizure of the engine parts for the purposes of this inquiry;
- The fact that all of the expert witnesses acknowledged, often at the instigation of cross-examination by counsel for the ATSB, Mr McIlwaine SC, that testing the fracture site to the extent that it is destroyed is the only way in which outstanding

questions about the presence of an inclusion at the fracture site origin can be established;

- On the basis of such evidence, such destructive testing was indeed carried out by McSwain Engineering Inc in the United States of America to the extent that it was no longer possible to examine the origin of the fracture first-hand;
- The ATSB had maintained a consistent line that the presence of inclusions in the No.5 journal, even if established, did not necessarily indicate that there were inclusions at the fracture site in the No.6 journal. After the fracture site had been destructively tested, testing of adjacent areas was the only testing which remained available to the ATSB for the purpose of their reopened inquiry, yet they insisted that it was necessary to do so.

13.23. In any event, the parts were returned to Australia pursuant to the orders I made, and further testing was carried out by the ATSB at its laboratories in Canberra. Their further report, consisting of 50 pages, is unsigned, although it bears the name Dr A Romeyn on its cover, and is dated April 2003. It is sufficient to quote the conclusions set out on page 50 of the report as follows:

> 'The chemical composition of crankshaft s/n V537912936 was within the limits specified in AMS 6414H with check test variation limits applied, with exception of two of the four carbon analyses. The results of carbon analysis show a higher degree of scatter than the other elements. The scatter range for carbon was 0.036%. The use of different analysis techniques and four independent analyses indicates that this degree of scatter appears to be inherent in the analysis of carbon in steel. The two carbon analyses that exceeded the upper check test variation limit did so by 0.02%, a value within the scatter range for the analyses conducted.
>
> The strength of the crankshaft core as determined by hardness testing is consistent with strength levels achieved by a single stage nitriding process. The strength of the core is determined by the tempering temperature. If the nitriding temperature exceeds the tempering temperature the strength will be reduced. The strength of the steel is not affected by the variations in carbon content within the range specified for the steel.
>
> The nitrided surface hardened zone complies with the specified requirements for case depth and surface hardness.
>
> The inclusion content of the steel is consistent with a steel treated with calcium and magnesium and produced by the vacuum arc remelted process. No inclusion stringers were observed. The maximum dimension of the inclusions observed was approximately 13μm.

No inclusions of a size greater than normal, or of a type different from the normal inclusions, were identified in the volume of steel surrounding the site of fatigue crack initiation.

There was no evidence of a non-metallic inclusion being the site of fatigue crack initiation.

Pullout features created under impact loading are considered to be a feature of the fracture of steels containing very low levels of non-metallic inclusions. These features do not represent material flaws or sites of lower material strength. No evidence of this type of feature was found in the vicinity of the fatigue initiation site.

Evidence of cracking, aligned with the axis of the journal with a microstructurally influenced crack path, was found extending from the step feature on both sides of the fracture. Cracking of this nature is consistent with cracking created by the localised thermal expansion of surface hardened zones.

The fracture surface features at the site of fatigue crack initiation had been damaged during the processes of final fracture and torsional separation.'

13.24. When these conclusions are considered in light of the body of knowledge we already have, it is clear that final, definitive proof that there was a non-metallic inclusion acting as a stress riser at the fracture site will never be found.

13.25. On the basis that this most recent investigation by the ATSB takes the matter no further, I am content to rely on the evidence before me.

13.26. Issues, Discussion and Conclusions – see Section 14

Further discussion of the issues arising from this section, and the conclusions to be drawn from them, appears in Section 14 of these findings.

14. Issues, discussion and conclusions

14.1. *Was there anything abnormal about the takeoff and climb phases of Flight 904? If so, does this indicate that damage occurred to either engine during these phases?*

14.2. Mr Cavenagh argued that there was not. When the performance of MZK during this phase of the flight was compared with radar traces of its performance on its previous flight, and with the performance of another similar aircraft, there was 'a high degree of consistency'. He said that in his opinion it was 'very unlikely' that the engine was detonating at that stage (T3558-59).

14.3. Mr Cavenagh also argued that if the engine had been malfunctioning at that time, it is likely that the pilot would have noticed it. He pointed to the incident in April 2002 when the crew noticed a vibration soon after takeoff. The crew also noted the falling manifold pressure and the increase in oil temperature. He pointed out that the engine in VH-LTW lost all but one litre of oil in a period of only eight minutes (T3595).

14.4. However, other pilots who gave evidence told me that these symptoms are not necessarily noticeable (see the evidence of Mr Usher T1652 and Mr Kuch T1414).

14.5. These arguments arose because of Mr Braly's suggestions that the right engine of MZK may have been damaged during the climb phase of flight because Whyalla Airlines was using a lean fuel mixture at a high power setting, which he said was likely to result in episodes of 'at least light or moderate detonation during some climbs on at least some cylinders' (Exhibit C196a, p20).

14.6. It is difficult to form definite conclusions on this issue. I accept Mr Braly's evidence which was so clearly substantiated by the demonstration at his test facility in Ada Oklahoma, that the settings adopted by Whyalla Airlines during climb were quite capable of producing detonation. It is now impossible to know whether some damage had already occurred to the No.6 piston in the right engine but had not yet extended to the stage that it was causing the engine to lose power. It could be, as happened in the incident on 9 September 1999, that the damage was done, but the vibration in the engine did not become apparent until the end of climb and the beginning of the cruise phase of flight. On the evidence before me, I am not prepared to agree with Mr Cavenagh that it was 'very unlikely' that the right engine of MZK was damaged during the climb phase of flight.

(Signed)

14.7. *What, if anything, is indicated by the fact that MZK flew at 6,000 feet at a groundspeed of up to 183 knots during the initial cruise phase of the flight?*

14.8. On the assumption that Mr Mackiewicz was flying MZK at the engine settings set down in the Whyalla Airlines Operations' Manual for the cruise phase of flight, and there is no evidence to suggest otherwise, it seems very unlikely that the engines would have been detonating during that period. Mr Braly said that it was 'virtually impossible' to cause one of these engines to detonate or preignite if the engine and ignition system are in proper operating condition at such low power settings. Since I have already rejected the idea that the spark plugs and magnetos were malfunctioning, there seems little evidence to support the theory that any damage was caused to either engine during this phase of flight.

14.9. That having been said, it is noteworthy that Mr Braly's investigations revealed that the hottest cylinder head temperatures are achieved when the engine is operating at between 25 and 50°F rich of peak (T3150). Such a setting is well within the parameters specified in the Pilot Operating Handbook, and indeed by Textron Lycoming in its handbook, for the operation of the engine.

14.10. Mr Scott Roberts, who owns a farm near Tickera on the eastern coast of Spencer Gulf in the general flight path of MZK, gave evidence at the inquest and said that at between 6:30 and 7:00pm he heard an aircraft overhead going towards Whyalla. He thought that the engine noise was unusually loud, when it would have been in the cruise phase of flight. The usefulness of this evidence was questioned by Messrs Usher, Zockel and Brougham, having regard to the fact that the aircraft was flying at 6,000 feet. Dr Zockel also pointed out that even if the No.6 piston in the right engine had holed by that time, the turbine would attenuate the pressure fluctuations so that the noise would have been reduced rather than increased once a hole had occurred. He thought that it was unlikely that the exhaust noise was passing directly through the hole in the crankcase and forming a noise at the breather pipe, and he also thought that if there had been combustion in the exhaust system, the turbine would have suffered damage which was not apparent when the wreckage was examined (see Exhibits C21 and C176).

14.11. On the basis of this evidence, I am unable to form any conclusions that anything untoward happened during this phase of Flight 904.

(Signed)

14.12. *Why did the groundspeed of MZK change at 1837:41 (in that it became variable and reduced to an average of approximately 176 knots) over the ensuing ten minutes?*

14.13. This is the first stage of Flight 904 at which there is a noticeable change of the performance of the aircraft which might suggest that one of the engines was malfunctioning. There was a wide divergence of views amongst the experts who gave evidence as to what may have occurred at this point.

14.14. The first school of thought is that the damage to the No.6 piston in the right engine may have become apparent by then, having occurred during or perhaps at the end of the climb phase of flight which had finished only three or four minutes earlier. Mr Kym Brougham speculated:

> 'With only a slight decrease in speed and no other significant symptoms, the pilot (Ben) would not have been very concerned and he would have continued with the flight to Whyalla oblivious to the damage already done to the engine.' (Exhibit C73e, p1)

14.15. He speculated that one spark plug may have become contaminated during the period the piston was melting or eroding during detonation, and continued operation after the piston was holed would have contributed to the build-up of deposits on the other spark plug. Dr Zockel agreed, saying that if one spark plug had been rendered inoperative because it had been shorted out by melted aluminium, even when the power setting of the engine is reduced, detonation might still have been possible because:

> 'It's easier for that end-gas to detonate with one spark plug because the flame front has to travel much further.' (T2091)

14.16. It is at this point that the ATSB's experts part company with all of the other experts who gave evidence in the inquest. They argued that at 1837:41, the No.6 crankshaft journal on the left engine fractured, but the two crankshaft sections remained dogged or keyed together and continued to rotate. It is speculated that 'relative movement between the journal fracture surfaces would have altered engine timing, causing rough running and loss of performance' (Exhibit C97, p110).

14.17. The ATSB argued that this interference with engine timing and consequent rough running would have been enough to cause the reduction from 183 to 176 knots.

14.18. Dr Romeyn pointed to the Sharp Aviation incident on 14 December 2001 to support this theory. He pointed out that in that case the engine continued to operate after the crankshaft had fractured and symptoms became evident to the crew. It is true that the engine in JCH did not suffer an immediate catastrophic failure. The symptoms progressed from an initial inability to synchronise the engines through to a failure of the vacuum pump driving the gyro on the right engine, to a loss of oil pressure and a rise in oil temperature, and a slight drop in cylinder head temperature.

14.19. However, it must be remembered that in the Sharp Aviation case, the failure of the crankshaft did not result in a hole in the crankcase which would have caused a much quicker loss of oil.

14.20. It seems to me that the failure sequence in the case of JCH is just as difficult to interpret as the sequence in the left engine of MZK, and that it is difficult to use one as an aid to prove the other.

14.21. Certainly, Mr Malcolm Sharp acknowledged that it was possible for the crankshaft to remain dogged after it completely fractured, but he doubted that it would remain so for an extended period (T2424).

14.22. Mr Barry Sargeant, the ATSB Senior Investigator who wrote the draft ATSB report, said that so long as the connecting rod end cap and bearing remained in place, the crankshaft would remain dogged and the engine should continue to operate at the same RPM (T3675). Consequently, he was unable to see that there would be any change in the power output of the engine, and inferentially, any difficulty in synchronising the engines. He said that it is difficult to conceive that there would be enough room within the end cap of the bearing for the two sections of the crankshaft to move at different speeds sufficiently to cause rough running, and the bearing remaining intact (T3676).

14.23. Mr Les Lyons, the CASA Technical Specialist - Powerplants, was also sceptical about this ‘dogging’ effect. He examined the surfaces of the two pieces of the fractured crankshaft (pictured page 55, Exhibit C97), and said that there was no evidence of significant fracture surface ‘smearing’, which would be caused by movement of the two pieces of the crankshaft against each other (T4488).

14.24. Mr Braly in his characteristically unequivocal manner, suggested that it would be virtually impossible for the crankshaft to remain dogged for the period of time suggested by the ATSB (T3211). He said that the enormous torsional forces involved in these engines are difficult enough for an intact crankshaft to withstand, let alone a fractured one.

14.25. If the opinion of Associate Professor Richard Taylor of the Department of Aviation, Ohio State University in the United States of America is to be accepted, the variations in groundspeed from 1837:41 onwards may have no significance at all. Professor Taylor suggested that the variations in groundspeed recorded by the radar equipment might simply have been due to variations in the strength of the signal, rather than actual variations in the speed of the craft. This opinion received some support from Mr Kell who conceded that fluctuations in groundspeed between 1836 and 1847 had been influenced by periods where one radar sensor had lost the track (T3756).

14.26. It is not possible to form a definite conclusion about which, if any, of these theories are entirely correct. I do not consider that the evidence is anywhere near clear enough to support the theory advanced by the ATSB that the crankshaft fractured at around 1837 and remained dogged until 1847. In view of evidence about what occurred later in the flight, which I will discuss presently, it seems to me that there are far more satisfactory explanations for what occurred.

14.27. *At 1847:15 the groundspeed of MZK reduced by another ten knots or so, its altitude increased by 100 feet, and its track diverged to the right by 19 degrees. What do these events indicate about the failure sequence of the engines of MZK?*

14.28. The divergence of MZK to the right by 19 degrees, and the reduction in its groundspeed by 10.1 knots, and the increase in its altitude by approximately 100 feet, were the events which received the most attention during the course of the inquest. Certainly, they represent the clearest departure from standard flight which can be discerned from the radar information until just before the ditching, when the behaviour of the aircraft became even more erratic.

14.29. The ATSB theory is that at this point the crankshaft in the left engine which had fractured 8 to 10 minutes earlier but had remained dogged, finally separated causing the engine to cease operating immediately (see table on page 111, Exhibit C97).

14.30. The question then arises as to why the aircraft diverged to the right rather than to the left, if it was the left engine that ceased functioning. All of the pilots apart from Mr Cavenagh, Mr Fearon and Mr Doug Stimpson, the pilot presented by Textron

Lycoming in the USA, argued that in the event of a left engine failure, the aircraft is much more likely to yaw to the left, since all the power is being produced on the right side of the aircraft.

14.31. To counter this argument, Messrs Cavenagh, Fearon and Stimpson argued that the aircraft would yaw to the right if the pilot, anticipating the left engine failure, overcorrected with right rudder. It is noteworthy that this issue was not canvassed at all in the ATSB final report, Exhibit C97.

14.32. It seems to have been first canvassed when Mr McIlwaine SC cross-examined Mr Malcolm Sharp. Mr McIlwaine SC produced Mr Mackiewicz's training documents, to which I have already referred, where an observation was made that Mr Mackiewicz was inclined to 'overcontrolling rudder' (T2455). Mr Sharp, who is a very experienced pilot, responded that even if there had been an overcorrection to the right, he would have expected an initial yaw to the left (T2460). Mr McIlwaine SC then put to Mr Sharp that, since the radar 'hits' were 3.7 seconds apart, the initial yaw to the left may have occurred during that space of time, and not have been recorded on the radar. Mr Sharp was unable to answer that question (T2460).

14.33. I find the ATSB's theory, namely that the left engine failed catastrophically at 1847:15, that if there was a yaw to the left that it occurred in less than 3.7 seconds and was not recorded on the radar, and that there was such a gross overcorrection that the aircraft yawed 19° to the right, as so unlikely as to be almost fanciful.

14.34. Mr Kym Brougham described the ATSB theory as 'very improbable' (T2789), and Associate Professor Taylor commented that you would need an 'ungodly' amount of rudder pressure to cause a deviation of that nature (T3050). Mr Auld gave evidence to similar effect (T3636).

14.35. In a final, almost embarrassing, attempt to justify the ATSB's theory, Mr McIlwaine SC put to Associate Professor Taylor that the yaw to the right may have been due to the pilot turning around to address his passengers and inadvertently turning the yoke to the right. Associate Professor Taylor described this as 'highly unlikely' (T3100), and the theory did not see the light of day again after that.

14.36. The alternative theory put forward by Mr Kym Brougham and others is that at 1847:15, the right engine began running roughly and, either through the gradual increase in the size of the hole in the No.6 piston, or because the pilot reduced power in that engine in order to protect it, the aircraft diverged to the right and lost 10.1 knots in groundspeed. I will deal with the groundspeed issue in due course.

14.37. This alternative theory was advanced by Associate Professor Taylor when giving evidence in the United States. After first addressing the possibility that there may have been anomalies in the radar information which may explain these events, he then went on to say:

> 'The other situation that occurred to me as I read through this material and studied this diagram (Exhibit C97, p113) is that the pilot may have perceived an engine that was running rough. Now, when you are in an aircraft like this and you perceive rough running - that's flight vibration or perhaps a very subtle change in some of the engine indicators - most pilots, before doing any tinkering, would probably want to disengage the auto pilot. Pilots like to have their hands on the controls, their feet on the controls, to feel what's happening, and that alone, disengaging the autopilot, hand flying the aeroplane, paying attention to engine indicators, perceptions, feelings, vibrations, whatever could easily result in any of these three disturbances, or the three of them combined.' (T3052)

14.38. Mr Braly also advanced a similar theory, noting that following the yaw to the right, the pilot corrected its course to a direct track to Whyalla. He said:

> 'It is my opinion that the pilot decided simply to throttle the right engine and, in the process of that, the aeroplane yawed to the right slightly. In my experience teaching multi-engine pilots to fly during training, a momentary lapse in the heading control of the aircraft during major left/right power discrepancies is more common than not, even among good pilots, and I think the right/hand turn data is consistent with that, and a prompt recorrection back on course is consistent with him having done that and then retrimmed the aeroplane by use of the rudder trim control and what not to put the aeroplane back on course.' (T3222)

14.39. The CASA expert, Mr Les Lyons, gave similar evidence (T4485), as did Mr Beattie (T1946), Mr Usher (T1654), Mr Sargeant (T3678) and Mr Thompson (T3816).

14.40. In my opinion, the evidence is overwhelmingly against the ATSB theory that the crankshaft in the left engine in MZK finally separated at 1847:15 resulting in a yaw to the right and loss of groundspeed. I found the evidence of the other experts who argued that the yaw to the right was much more likely to have been the result of loss of partial performance in the right engine much more convincing. For the reasons which I will address next, the ATSB theory seems to fly in the face of common sense and the vast experience of the people who gave evidence to the contrary.

(Signed)

14.41. *After 1847:15, MZK continued to fly at an average groundspeed of approximately 167 knots. What does this indicate about whether either or both engines were still operating, and to what extent, during this period?*

14.42. Another issue which was debated vigorously during the inquest was whether the aircraft was capable of maintaining the groundspeed of approximately 167 knots indicated by the radar equipment if, as the ATSB asserts, the left engine had failed completely at 1847:15.

14.43. The vast majority of the pilots who gave evidence said that they would expect a reduction of between 30 and 50 knots in the event of a total engine failure (Mr Kym Brougham at T2372, Associate Professor Taylor at T3042, Mr Thompson at T3816, Mr Heyne at T215, Mr Usher at T1681, Mr Hill at T1851, Mr Beattie at T1947, Mr Sharp at T2397). Information obtained by counsel assisting from four senior engineers from Piper Aircraft Corporation, but which is unsworn and untested by cross-examination, also tends to support this argument (see Exhibit C226).

14.44. This issue is central to the ATSB theory about the origin of the damage to the right engine as well as the failure of the left engine. The ATSB argued that following the total failure of the left engine at 1847:15, the pilot 'firewalled' the right engine. The word 'firewalled' is normally used by pilots to mean pushing all three engine management levers, namely the throttle, mixture and propeller pitch levers, forward towards the firewall to their maximum power setting. This term was used rather loosely by Mr Cavenagh in this case, because it is also central to his theory that Mr Mackiewicz caused the detonation damage in the right engine by failing to move the mixture lever to full rich after moving the throttle to full power, thereby 'overboosting' the engine and causing the detonation damage which ensued.

14.45. Mr Cavenagh pointed to the forced landing incident at Maitland in January 2000 as an incident where Mr Mackiewicz had experienced an inability to maintain height after losing one engine, and said that this experience may have led him to take drastic action in order to enable him to maintain height and airspeed on 31 May 2000. As I have already discussed, this is not the evidence. There is no evidence that Mr Mackiewicz was so stressed or agitated that he would have made such an obvious error, and failed to correct it for more than 14 minutes.

14.46. In answer to those who suggested that the aircraft was not capable of maintaining the groundspeed indicated by the radar equipment on one engine, Mr Cavenagh resorted to theoretical calculations to establish that it was possible, at maximum power output, for MZK to have maintained that height and groundspeed. Allowing for a tailwind component of 20 knots, and there was some debate about that, the true airspeed (TAS) of MZK was an average of 147 knots after 1847:15.

14.47. Mr Cavenagh argued, on the basis of graphs and other information provided by Piper Aircraft Corporation and Textron Lycoming, in order to fly at 147 knots TAS at 6,000 feet, at standard temperature, using one engine only, would require that engine to produce between 365 and 372 brake horsepower. Also using that technical information, he calculated that in those climatic conditions, with the propeller rotating at 2,575 RPM, the mixture set at full rich, and the manifold pressure set at 46 inches of mercury, the LTIO-540-J2B Textron Lycoming engine was capable of producing 370 brake horsepower. Mr Cavenagh even went so far as to argue that because these engine figures were obtained from bench-tested engines and not engines moving through the air at altitude, and because there is an assumption that the engine was running at full rich mixture rather than leaned back to obtain even further power, and further allowing for the possibility that the propeller in this case may have only been rotating at 2,400 RPM which would create even greater propeller efficiency than if it was rotating at 2,575 RPM, the engine was capable of even greater performance than that (T3535-38).

14.48. The tolerances established by Mr Cavenagh's theory are extremely narrow. His theory seems to require that in order to achieve this performance, Mr Mackiewicz firewalled the throttle and either deliberately leaned the mixture to best power thereby putting the engine at risk of catastrophic damage, or he failed to adjust the mixture and thereby accidentally hit upon a best power setting and thereby achieved this outstanding performance (T3542). Any variance from the factors assumed by Mr Cavenagh would invalidate his theory. For example, if the tail wind was not 20 knots, but 13 knots as established by Mr Sargeant (T3688), or as low as 10 knots as noted by Flight Lieutenant Freeman (Exhibit C108a), then it was not possible for MZK to achieve a TAS of 147 knots on one engine. Mr Fearon conceded this point (T4347).

14.49. I agree with the comment of Mr Braly when he said:

> 'So I would say you have to push all the assumptions way out to the boundaries and then fudge it some more to get to the point that you accept that he had the (right) engine feathered at 147 knots, or some air speed close to that.' (T3225)

Although Mr Braly was discussing the feathering of the right engine at the time, the point he made is a general one and applies to single engine performance in the event that either engine was feathered for whatever reason.

14.50. After evidence was taken in the United States of America, Mr Braly attempted to recreate these circumstances using an almost identical Piper Chieftain aircraft. He took a video film of the instruments during the relevant parts of the journey (Exhibit C196m). Mr Cavenagh pointed out that Mr Braly was able to achieve 363 brake horsepower without firewalling his engine (T3543) and Mr Fearon pointed out that Mr Braly achieved a true airspeed (TAS) of 147.7 knots on his calculations. Mr Braly, on the other hand, pointed out that on his calculations the TAS was 144 knots, and that his aircraft was 350 pounds lighter than MZK and equipped differently in that it was fitted with intercoolers and winglets. He said:

> 'Allowing for these differences, an airspeed of around 140KTAS is the upper limit of speed that one would expect out of MZK on the night of the accident.' (Exhibit C196m)

14.51. To complicate the issue further, MZK's engine was fitted with a 'density controller' which governs the boost pressure provided by the turbocharger to the manifold pressure of the engine. In motor vehicles with turbocharged engines, the density controller is called a 'waste gate'. Mr Karl Jelinek, the aircraft maintenance engineer, said that the density controller on these engines is designed to limit the power output of the engine to 350 brake horsepower (Exhibit C147e). Mr Jelinek went on to say that the density controller is governed by an airworthiness direction which requires it to be checked every 100 hourly service. The documents indicate that in the case of MZK, the density controller was checked during the Check 2 and 3 inspection which culminated on 30 May 2000, the day before the accident (see Exhibit C150).

14.52. Mr Fearon conceded that if the density controller was properly adjusted, and in all respects the engine system was working properly, the power output of the engine was limited to 350 brake horsepower (T4369).

14.53. So, in addition to the other factors which must have been present, the density controller in the turbocharger of the right engine must have been malfunctioning in order to allow the engine to be producing between 365 and 372 brake horsepower.

14.54. This is another area where Textron Lycoming criticised the ATSB draft report. There was no examination of the density controller of either engine of MZK after the wreckage was found to see whether they were set correctly.

14.55. As each of these technical issues were put to Mr Cavenagh and Mr Fearon, their explanations and arguments became more abstruse and less credible. (See for example Mr Harvey's cross examination of Mr Fearon at T4369-70). I gained the very distinct impression that this constituted an *ex post facto* justification for a conclusion that had already been reached, rather than a genuinely dispassionate scientific analysis of the factors involved.

14.56. The factor which I find most compelling in relation to this issue is that raised by Professor Taylor in the United States of America, namely that even assuming that the engine was capable of producing that amount of power, which seems highly improbable, why would Mr Mackiewicz have flown the aeroplane in that manner when it was so totally unnecessary? He said:

> '….but based on the fact that if the engine had failed at 1847:15 and if the pilot firewalled, if you will, the right engine in the process of securing the aeroplane - getting things straightened around - it is my opinion that he would have discovered that he was able to maintain the most efficient air speed probably with less than maximum power, which I think a prudent pilot would do, because he knows that if he runs his only remaining engine at full power he is taking a chance on its continuing to run for the rest of the flight. The pilot would consider that a very remote chance that the other engine would fail; nevertheless, when you have only one left, you treat it with kid gloves.' (T3081)

14.57. Mr Sargeant expressed the same view (T3719). He said that even if a pilot might have momentarily firewalled the throttle without adjusting the mixture (which would seem to go against the most basic instinct of pilots), it seems inconceivable that he would allow that situation to continue for eight minutes, until the aircraft reached top of descent, and without advising any of the appropriate authorities what was going on (T3720). Mr Thompson gave similar evidence (T3817).

14.58. In considering the totality of this evidence, I am not satisfied, even on the balance of probabilities, that the right engine of MZK was capable of propelling the aircraft by itself at 147 knots TAS for eight minutes. It seems so highly improbable that the pilot would either deliberately or accidentally overboost the engine to that extent, thereby putting its integrity at risk, when he had already lost one engine, and was flying over water, in circumstances where it was completely unnecessary to do so, and where the remaining engine was quite capable of propelling the aircraft at a lower speed and maintaining altitude in relative safety.

14.59. *At 1855:43, at least one of the engines of MZK was noted to be operating at 2,400 RPM, 200 RPM faster than the usual 2,200 RPM for that phase of the flight. What does this indicate about the failure sequence of the engines of MZK?*

14.60. At 1855:43, during Mr Mackiewicz's acknowledgement to Melbourne Centre that radar services were being terminated, Mr Kell's audio analysis reveals either one or both propellers were revolving at 2,400 RPM (Exhibit C214a, p11).

14.61. If Mr Mackiewicz had 'firewalled' the engine as the ATSB suggested, it would have been operating at 2,575 RPM. However, it must be acknowledged that 2,400 RPM is higher than the usual setting for the cruise phase of flight, namely 2,200 RPM. This was the setting at 1833:54, as detected by Mr Kell.

14.62. This evidence suggests that Mr Mackiewicz may have boosted power on the left engine to compensate for 'throttling' or decreasing power on the right engine if he was experiencing vibrations or inability to synchronise. This theory was put forward by Mr Braly who said:

> 'At that point in time the pilot had an unknown problem with the right engine, but it was still operating, and he had a 250 or 260 hour left-hand engine, and he made the decision to continue on. In the process he would have likely pushed up the power on the left-hand engine to something approaching climb power. He may have in fact used climb power - that would be a common training scenario for a multi-engine pilot, that if you lose an engine, you put the other engine up to climb power. That's not necessarily the most optimal training exercise, but it is a common method of teaching multi-engine pilots.
>
> So I believe he increased the power on the left engine as he reduced the power on the right engine, and pressed on.' (T3222)

As has been previously discussed, the appropriate setting for climb power is 2,400 RPM.

14.63. Messrs Kuch (T1464) and Beattie (T1948) also speculated that the only reason why Mr Mackiewicz may have increased the RPM from the usual 2,200 would be if there had been a problem with one of the engines. Mr Kym Brougham agreed, saying that 2,400 RPM is 'not a normal power setting' (Exhibit C73e, p3).

14.64. It seems to me that this is the most logical and likely explanation for this piece of evidence.

14.65. *MZK commenced its descent into Whyalla at 1855:54, and Mr Mackiewicz advised Adelaide Flight Information Service that he was estimating arrival at Whyalla at 1908. Both of these events were in accordance with usual practice. What does this indicate about the failure sequence of the engines of MZK?*

14.66. According to the radar information, MZK commenced its descent towards Whyalla at 1855:54.

14.67. The fact that MZK commenced its descent at that point, suggests that Mr Mackiewicz was still not worried about the ability of the engines to get him and his passengers to Whyalla. Several of the pilots who gave evidence explained that if he had been so concerned, he would have delayed his descent until much later in the flight, thereby giving him the greatest opportunity to glide in the event that he suffered further problems. For example, Mr Usher argued that Mr Mackiewicz would not have commenced descent if there had been an engine problem, and would have remained at high altitude and in radar coverage if that were the case (T1703 and T1733). Mr Sharp (T2418) and Mr Brougham (Exhibit C73e, p4) agreed, as did Mr Sargeant (T3691).

14.68. Mr Brougham pointed out that at 1856:03, Mr Mackiewicz advised Adelaide Flight Information Service that he was estimating Whyalla at 1908, which again suggests that he expected to arrive in Whyalla on schedule.

14.69. In my opinion, these facts also support the theory that although Mr Mackiewicz may have suffered a partial loss of power in one engine, he was still maintaining satisfactory airspeed and altitude from both engines to the extent that he was comfortably able to estimate that he would arrive in Whyalla on time. It does not suggest that he had suffered a catastrophic failure in the left engine, and had overboosted the right engine to maximum power in order, for some reason, to maintain altitude and speed when it was not necessary to do so.

14.70. *At 1858:30, the rate of descent of MZK increased from the usual 400 to 650 feet per minute. What does this indicate about the failure sequence of the engines of MZK?*

14.71. It was at this point that it would appear that major problems had developed with MZK. The radar information suggests that MZK's rate of descent increased from 400 feet per minute (which is quite usual) to 650 feet per minute at 1858:30.

14.72. Mr Brougham argued that if, at that time, Mr Mackiewicz had lost only one engine, he could have maintained his rate of descent at 400 feet per minute. He argued that the 650 feet per minute rate of descent is more consistent with one engine having failed completely and one operating at partial power (T2763). What is clear is that at a rate of descent of 650 feet per minute, MZK was not going to reach Whyalla, so it must be concluded that this was not a deliberate move by the pilot (see the evidence of Mr Cavenagh at T3530). Further, if both engines had been lost by then, the rate of descent would have been more like 1000 feet per minute (see Mr Cavenagh's evidence at T3531).

14.73. At page 111 of the ATSB final report, in the section marked 'Likely sequence of events', it is speculated that at around this time the No.6 piston in the right engine had holed by melting, the engine operation was restricted to five cylinders, the piston damage resulted in crankcase pressurisation, some but not all engine lubricating oil was vented overboard, the piston hole was also likely to have affected the intake pressures and turbocharger operation in a cyclic manner leading to engine power surging over which the pilot would have no control.

14.74. Mr Kym Brougham argued that at some stage after top of descent, Mr Mackiewicz may have become aware of problems with the left engine, probably a decrease in oil pressure and an increase in oil temperature, and as a result of this he may have opened the cowl flaps on the left engine to cool it. At this stage, the left engine crankshaft may have broken and the left engine would have shut down almost immediately. Due to the loss of oil pressure, the propeller would have automatically feathered. This meant that the right engine was providing very little forward thrust and the left engine none at all. At this stage, he would have issued the Mayday transmission advising that he had lost both engines. Mr Brougham speculated that Mr Mackiewicz may

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have been trying to increase the power on the right engine again, or he was trying to restart it again if he had shut it down completely, at the time of impact (Exhibit C73e).

14.75. In support of Mr Brougham's theory, the ATSB did establish that the propeller on the right engine was in a normal operating pitch range, and not feathered at impact with the water. This can not be conclusively established however, since it is possible that the propeller blades could have moved to the feathered position, the position in which they were found when the wreckage was removed, as a result of oil pressure 'leak down' (Exhibit C97, p54).

14.76. Mr Sargeant had a similar opinion (T3678-98), as did Mr Lyons (T4485-87).

14.77. *Why was no Pan or Mayday call made prior to 1901:14?*

14.78. I have already mentioned that at no stage prior to 1901:14, when Mr Mackiewicz issued the Mayday call, did he express any concern over the radio about the performance of the aircraft. He had a conversation with Melbourne Centre at 1855:37, and a conversation with Adelaide Flight Information Service at 1856:03, when he reported his position and expressed no concern whatsoever. It is difficult to conceive that he would have behaved in this way if, on the ATSB theory, he had experienced a catastrophic failure of the left engine at 1847:15, and had overboosted the right engine to compensate.

14.79. A Pan call is a call made by a pilot in circumstances where there is significant cause for concern, and there may be the need for emergency services to be alerted at the destination airport, but where the circumstances are less urgent than would require a Mayday call, which signifies that lives are in imminent danger.

14.80. It should be recalled that at 1847, MZK was still over land, and could easily have diverted to Kadina or Port Pirie (see the evidence of Mr Kuch T1491, Mr Sharp T 2398, Mr Kym Brougham T2550, Mr Auld T3609-10; and Mr Usher T1656). At that point, AirServices Australia could have assisted the pilot over the radio, as MZK was still in radar range at that point (see the evidence of Mr Milton T176).

14.81. Mr Cavenagh said that it would have been good airmanship for Mr Mackiewicz to have made some sort of radio transmission after 1847 if, as his theory would have it, he had lost the left engine at that point (T3561). He would not accept that Mr

Mackiewicz's failure to make a Pan call after that point was inconsistent with his theory. He simply pointed to what he described as 'human behaviour', and referred to a number of examples where experienced and competent pilots have made egregious errors of judgement (T3562).

14.82. It seems to me, however, that the errors that Mr Cavenagh referred to were made on the spur of the moment in the process of the takeoff or landing, and not during the cruise phase of flight when the pilot had 8-10 minutes to correct whatever error he may have made. I do not consider that the errors Mr Cavenagh has identified really assist in understanding what may have happened over Spencer Gulf that night.

14.83. In my opinion, the absence of a Pan call, or indeed any evidence that Mr Mackiewicz was concerned between 1847 and 1901, is much more consistent with the theory that problems with the right engine had begun to develop at 1847, but they were not so serious as to cause Mr Mackiewicz concern. As Mr Sargeant outlined:

> 'A: Initially I would have expected a pilot to try and find out what the problem was. The right engine would be probably running a little roughly, could be due to a number of reasons. He would go through his trouble checks. Clearly he wouldn't have been able to correct the problem. He wouldn't know that it was a holed piston. He would know that it was certainly running a little roughly, wasn't developing as much power as it was before. It's likely he would have continued with the reduced power. I would have thought that it would have been better for the pilot to have given a pan call at that point; he evidently didn't. He may have thought that it wasn't a major problem; might have been perhaps a couple of spark plugs on one cylinder out or for whatever reason, I don't know, but he may not have considered it to be a major problem. He just elected to nurse the right engine and then they could sort it out when they got to Whyalla.' (T3686-87)

14.84. The more likely scenario, in my opinion, is the one outlined by Mr Brougham and Mr Sargeant that although problems with the right engine had begun to develop at 1847, they were not so serious as to cause Mr Mackiewicz concern. When considered along with the other evidence of Mr Mackiewicz's apparent calmness in the radio transmissions at that time, his decision to commence descent at the usual time, his estimate that he would make Whyalla on time, and the fact that he had only increased the engine speed to 2,400 RPM rather than 'firewalling' it, all suggest to me that he was still in control of the situation and did not consider the flight in imminent danger. I accept the opinion of Mr Braly when he said that it was 'almost inconceivable' that, if Mr Mackiewicz had suffered a catastrophic failure of the left engine resulting in feathering of the propeller, he would not have reported an emergency over the radio (T3223).

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14.85. *What was the cause of the failure of the left engine of MZK?*

14.86. This is the issue which is the subject of the most fundamental disagreement between the expert witnesses who gave evidence at this inquest.

14.87. I have set out the conclusion reached by the ATSB in the Executive Summary of the Final Report at paragraph 9.25. It can be summarised as:

- The crankshaft of the left engine fractured at the No.6 connecting rod journal as a result of fatigue cracking, which was initiated by the presence of a planar discontinuity in the journal surface;
- The discontinuity had been caused by localised thermal expansion of the nitrided journal surface as a result of contact with the edge of the No.6 connecting rod big end bearing insert;
- The crankshaft failed approximately 50 flights after fatigue crack initiation;
- The contact with the edge of the No.6 bearing insert occurred because the bearing insert was damaged during engine operation as a result of high bearing loads created by lead oxybromide deposit-induced preignition, and lowered bearing insert retention forces associated with the inclusion of an anti-galling compound between the bearing inserts and the housings;
- The left engine probably continued to operate for 8-10 minutes as a result of being ‘dogged together’ before the two pieces finally disconnected resulting in loss of drive to the magnetos, fuel pump, camshaft which would have led to the sudden stoppage of the engine and the feathering of the propeller.

14.88. This was the theory put forward by Mr Cavenagh during his evidence, and further explained by Dr Romeyn.

14.89. I have also mentioned that these conclusions were questioned by Textron Lycoming in their letter to the ATSB dated 23 April 2001, particularly on the basis that Whyalla Airlines was operating within the engine operating limits, they disputed the suggestion that the anti-galling compound was involved, there was no sign of progressive failure of the bearings during servicing of the aircraft and other matters (see paragraphs 9.17-9.22).

14.90. Although the information I have about the engine failures in the United States of America is meagre, it would appear that this is the only incident in a series of fifteen or more in which these conclusions have been reached - in the others, a defect in the material of the crankshaft has been identified as the cause in seven cases, and is suspected as the cause in the others. It seems to me that the ATSB is ‘swimming against the tide' to some extent, having regard to the overwhelming nature of the recalls by Textron Lycoming on a world-wide basis in 2001 and 2002 since this incident, citing defective crankshafts.

14.91. The scientific investigation carried out for the purpose of this inquiry has also raised a number of other points which, in my opinion, contradict the results of the ATSB investigation. Professor King found that even if there were lead oxybromides present in the left engine, they were confined to one small area of one piston which, in a startling coincidence, was the spot where the ANU took one of two samples leaving nothing on the rest of that piston crown and nothing on any of the other pistons tested. Even if they were present, they were not present in sufficient quantities to be considered relevant to the failure of the left engine.

14.92. Dr Zockel told me that the failure of the crankshaft in the left engine was initiated when the journal was in tension, and not in compression, and hence any suggestion that abnormal combustion was occurring in that cylinder is irrelevant. It was his opinion that the fatigue cracking at the No.6 journal of the crankshaft led to the destruction of the bearings, rather than the other way around.

14.93. The investigations of Dr Powell and Mr McLean led to the conclusion that there were high temperature iron oxide inclusions beneath the surface of the No.5 journal in the left engine crankshaft, and that it is likely that there were similar inclusions in the No.6 journal where the fracture occurred of sufficient size to affect the tensile and torsional strengths of the crankshaft. Further, they concluded that the physical features of the fatigue crack were more consistent with subsurface initiation rather than surface initiation through thermal causes, as postulated by the ATSB.

14.94. Mr McLean also made what I regard as the common-sense observation that it was difficult to accept that a bearing which had failed to the extent that it was rubbing on the journal fillet radius, thereby causing thermal cracking, leading to initiation of the fatigue crack, would survive for 50 flights after the fatigue crack initiation until it finally failed on 31 May 2000.

14.95. The evidence of Mr Braly argues that discussion of deposits in the left engine and lead oxybromides in that context is a 'red herring', and had nothing to do with the left engine failure. He also argued that abnormal combustion during the climb phase of flight may have initiated or exacerbated fatigue cracking in the left engine crankshaft (depending on whether one accepts Dr Zockel's opinion outlined above).

14.96. The evidence arising from Mr Hood's investigations in the United States of America supports Dr Powell's conclusions that the fatigue cracking in the left engine crankshaft was subsurface initiated and not consistent with thermal cracking, and not consistent with a shift of the No.6 connecting rod bearing resulting in rubbing at the crankshaft journal radius. He concluded that other damage to the connecting rod and other sections of the crankshaft were secondary to the initial failure at the No.6 journal and not the other way around. He concluded that the subsurface initiation of the fatigue fracture was a result of a manufacturing-related material condition in the crankshaft.

14.97. Mr Hood's examinations did not reveal the presence of an oxide inclusion at the fracture initiation site, however there was a 'small pocket' at that point at the centre of the circularly radiating crack front, in which the presence of aluminium, calcium, magnesium and oxygen were indicated. No large oxide inclusions or an oxide inclusion seam were observed at the fracture initiation point, although small randomly dispersed calcium-rich oxide inclusions measuring 5-10 microns were observed in the cross section of the sample. If there had been an inclusion in the pocket area, this may have been lost during the fracture process.

14.98. In my opinion, the overwhelming weight of this evidence is against the ATSB analysis of the cause of the failure of the left engine of MZK on 31 May 2000. The weight of that evidence is much more strongly in favour of the proposition that the fatigue crack in the No.6 journal in the crankshaft of that engine was initiated as a result of a subsurface defect in the steel of the crankshaft as a result of a manufacturing flaw which created a point of weakness from which fatigue cracking radiated outwards over the ensuing 50 to 70 flights until it finally fractured on the night of 31 May 2000.

14.99. *What was the cause of the failure of the right engine of MZK?*

14.100. I have already mentioned the apparent contradiction, between Mr Cavenagh's theory that Mr Mackiewicz advanced the throttle on the right engine to maintain altitude without moving the mixture level to full rich, thereby causing abnormal combustion and the holing of the No.6 piston in the right engine, and the evidence of Dr Romeyn that the presence of the carbonaceous deposits on the No.6 piston in the right engine suggested that detonation is likely to have occurred under rich rather than lean mixture conditions. In other words, the Cavenagh theory is that Mr Mackiewicz unduly leaned the engine, whereas Dr Romeyn's evidence suggests that the damage occurred when the engine was at a richer than usual power setting.

14.101. What does seem clear is that detonation in the right engine was unlikely to have occurred while the engine was in a cruise power setting, unless one of the spark plugs had been rendered inoperative by detonation damage which had occurred earlier in the flight, perhaps during the climb phase, as suggested by Mr Braly.

14.102. This would seem consistent with what happened in April 2002 when the aircraft LTW took off from King Island and sustained similar damage while the engine was in a climb power setting. Similarly, the incident on 9 September 1999 involving BYG occurred while the aircraft was in a climb/cruise setting. In contrast was the damage to BYG in February 2000 where it seems apparent that the detonation happened while the aircraft was in cruise although it can not be excluded that the damage occurred during climb and did not become apparent until some time later.

14.103. Having regard to the totality of the evidence, I reject the argument put forward by Mr Cavenagh and Mr Fearon that the damage to the right engine was caused as a result of Mr Mackiewicz 'overboosting' the right engine as a result of the left engine having failed first. For reasons which I have already expressed, I do not regard this as the most likely scenario. Having regard to the evidence of Mr Braly and Dr Zockel and others, it seems more likely that the right engine of MZK was damaged due to end gas detonation during the climb phase of Flight 904 and that Mr Mackiewicz reduced the power on that engine in order to conserve it at 1847:15.

14.104. *Did the left engine fail first? If so, at what stage of Flight 904?*

14.105. For the reasons expressed above, I conclude that the right engine of MZK began showing signs of rough running and loss of power, due to end gas detonation damage, at 1837:41, and that Mr Mackiewicz reduced power on that engine causing a yaw to the right at 1847:15. The evidence also suggests that he may have increased the RPM in the left engine to 2,400 in order to compensate somewhat for the loss of power in the right engine. This did not constitute 'overboosting' the engine, and was within the specifications in the Pilot Operating Handbook. It is my

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conclusion that the left engine failed suddenly when the crankshaft fracture was complete and the two pieces separated at around 1858:30 when the rate of descent increased from 400 to 650 feet per minute. It may be that Mr Mackiewicz then increased the power on the right engine to try and maintain altitude, but the right engine was incapable of producing sufficient power to do so. There is some evidence that the right engine was still operating when MZK impacted with the water.

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15. Recommendations

15.1. The power to make recommendations

Section 25(2) of the Coroners Act, 1975, creates the power to make recommendations following an inquest. It provides:

> 'A coroner may add to his or her finding any recommendation that might, in his or her opinion, prevent, or reduce the likelihood of, a recurrence of an event similar to the event that was the subject of the inquest.'

15.2. It is noteworthy that the section does not create an unrestricted power. The recommendation must be such that it might, in the opinion of the coroner, prevent or reduce the likelihood of a recurrence of a 'similar' event. The power does not extend to issues which, although important, do not relate to the subject event. It would not be enough that a proposed recommendation in this case might be directed to aircraft safety generally.

15.3. The word 'similar' in section 25(2) is somewhat enigmatic in this context. I consider that it enables me to make recommendations which may prevent a recurrence of an incident which is not necessarily identical to the incident under consideration, but which is similar enough that the evidence taken in the subject inquest is sufficient to provide a basis for considering wider recommendations.

15.4. I am constrained by the Coroners Act, 1975, from inquiring any more widely than the cause and circumstances of this particular inquest, even if to do so might give rise to a useful recommendation (see the remarks of Lander J. in WRB Transport & Ors v Chivell [1998] SASC 7002, paragraph 18).

15.5. Role of the ATSB

The powers granted by the Coroners Act, 1975, are quite similar to the powers granted to the ATSB by the Air Navigation Act, 1920. Section 19CA of that Act provides:

> 'The object of this Division is, by the establishment of a system of investigation for determining the circumstances surrounding any accident, serious incident, incident and safety deficiency, to prevent the occurrence of other accidents, serious incidents, incidents and deficiencies. It is not part of the object of this Division:
>
> (a) to provide the means of apportioning blame for the occurrence of an accident, serious incident, incident or safety deficiency; or
>
> (b) to provide the means of determining the liability of any person in respect of an accident, serious incident, incident or safety deficiency.'

15.6. The prevention power in section 19CA is wider than mine in the sense that it can be used to prevent 'other accidents, serious incidents, incidents or deficiencies', which I understand to mean accidents generally, whether similar to the subject accident or not.

15.7. The statement in section 19CA that it is not part of the object of the legislation to apportion blame, or to provide the means of determining liability (presumably both criminal and civil) is also echoed in section 26(3) of the Coroners Act, 1975, which states:

> 'A coroner holding an inquest must not in the inquest make any finding, or suggestion, of criminal or civil liability.'

15.8. This subsection does not detract from the primary duty to determine the cause and circumstances of the death. As Nyland J. said in Perre v Chivell [2000] SASC 279 at paragraphs 54-56:

> 'It is clear therefore that the jurisdiction of the coroner is limited to making findings of fact. It is not his/her task to attribute or hint at blame…..In other words, the factual findings of themselves cannot be said to be findings of criminal or civil liability. A finding of criminal or civil liability requires the application of the relevant law to the facts in order to determine whether the essential elements of a given crime or civil obligation have been made out. It is not the coroner's role to undertake this process, it is the role of the courts, and this is what s 26(3) was enacted to ensure.'

15.9. In my opinion, Her Honour's remarks are equally apt to the powers granted to the ATSB by the Air Navigation Act, 1920. Section 19CA does not in any way limit the power of the ATSB to apply vigorous and professional investigatory techniques to an investigation, nor does it limit their power to draw clear conclusions of fact from that investigation. Indeed, it is essential that they do so, because unless they do, they will be unable to fulfil their statutory responsibility to prevent other such incidents.

15.10. It follows, then, that I reject any suggestion that the ATSB were constrained or limited by section 19CA of the Air Navigation Act, 1920 in this investigation. In my opinion, the remarks of the Director of the ATSB, Mr Kym Bills, to the Australian Senate on 11 February 2003 reflect this misconception:

> 'For many years there have, from time to time, been difficult issues in some state and territory coronial inquests. The ATSB has been seeking better mutually cooperative relationships with coroners in the context of the legislation currently before the parliament and will continue to do so. However, problems remain when the bureau is criticised at inquests for not spending more money on a particular investigation to satisfy

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> legal queries such as those relating to future civil litigation; when the high cost of inquests redirects our resources from higher safety priorities; where a particular inquest encounters difficulties with the Commonwealth no-blame legislation; under which we operate in accordance with international agreements; or where legal certainty is sought from an investigation, whereas the evidence often does not allow this and the ATSB's focus is on the action necessary for future safety.'

The notion that 'legal certainty' (by which I assume Mr Bills means the finding of a fact to the requisite standard of proof) is somehow inconsistent with the ATSB's role to ensure 'future safety' is not in accordance with logic. Surely an investigation must demonstrate, to an appropriate degree of certainty, that an incident has occurred in a particular way before remedial or preventative measures can be taken.

15.11. I note that there is currently a Transport Safety Investigation Bill 2002 before the Commonwealth Parliament. Section 7 of the Bill repeats the statements of section 19CA of the current Act, about what are <u>not</u> the objects of the legislation, and adds to that list:

> '(c) assisting in court proceedings between parties (except as expressly provided by this Act);
>
> (d) allowing any adverse inference to be drawn from the fact that a person is subject to an investigation under this Act.'

15.12. Once again, the objects of section 7 of the proposed legislation are not:

> '(a) to provide the means of apportioning blame for the occurrence of an accident, serious incident, incident or safety deficiency; or
>
> (b) to provide the means of determining the liability of any person in respect of an accident, serious incident, incident or safety deficiency;
>
> (c) assisting in court proceedings between parties (except as expressly provided by this Act);
>
> (d) allowing any adverse inference to be drawn from the fact that a person is subject to an investigation under this Act.'

15.13. I see no inconsistency between those provisions and my role pursuant to the Coroners Act, 1975 (SA), and indeed the role of other coroners around Australia.

15.14. <u>Recommendations made by the ATSB</u>

These appear at pages 121-124 of the ATSB final report (Exhibit C97). I have not adopted all of them for a combination of reasons. Firstly, as I have said, the power of the ATSB to make recommendations is wider than mine. Secondly, a number of the ATSB recommendation's are based on findings of fact with which I disagree.

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15.15. Combustion deposits

Recommendation R20010254 suggests 'a review of the certification requirements of piston engines with respect to the operating conditions under which combustion chamber deposits that may cause preignition are formed'. I have found that combustion deposits played no part in the failure of either engine of MZK on 31 May 2000, so I do not adopt that recommendation.

15.16. Anti-galling compounds

Similarly, ATSB Recommendations R20010255 and R20010256 deal with anti-galling compounds. I have found that they played no part in the failure of MZK's engines on 31 May 2000, so I do not adopt those recommendations.

15.17. Reliability of Aircraft Propulsion Systems within Australia

ATSB Recommendation R20010257 is as follows:

> 'The Australian Transport Safety Bureau recommends that the Civil Aviation Safety Authority review the operating and maintenance procedures for high-powered piston engines fitted to Australian registered aircraft to ensure adequate management and control of combustion chamber deposits, preignition and detonation.' (Exhibit C97, p121)

On my findings, there was no demonstrated defect in operating or maintenance procedures which may have led to the failure of either of MZK's engines on 31 May 2000, so I do not adopt that recommendation, except the issue discussed in the next paragraph.

15.18. Fuel Mixture Leaning Practices

ATSB Recommendation R20000250 was as follows:

> 'The Australian Transport Safety Bureau recommends that the Civil Aviation Safety Authority alert operators of aircraft equipped with turbo-charged engines to the potential risks of engine damage associated with detonation, and encourage the adoption of conservative fuel mixture leaning practices.' (Exhibit C97, p122)

The final report records that CASA's response was as follows:

> 'CASA also accepts Recommendations [sic] R20000250 and has published an article in the January/February aviation safety magazine Flight Safety Australia. Furthermore, CASA is considering further action on this matter and is consulting the aeroplane and engine manufacturers with a view to them improving their engine leaning procedure.'
>
> (Exhibit C97, p122)

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On my findings, the only departure from appropriate fuel leaning practices, as stipulated in the Pilot Operating Handbook (Exhibit C170g) which may have been causative of damage to either engine of MZK on 31 May 2000 was the leaning to 27usg/hr during the climb phase of Flight 904. I am satisfied, on Mr Braly's evidence, that the fuel leaning guidelines stipulated by Whyalla Airlines in its Operations Manual (Exhibit C73h), were inappropriate and may have caused or exacerbated damage to the piston of the right engine.

15.19. I agree with the submission of Messrs Harvey and Roser, counsel for CASA, at page 32:

> 'The evidence discloses an urgent need for the technical review of the detonation survey upon which the procedures of the FAA approved Flight Manuals and Lycoming endorsed, Piper POHs are based. That review should be undertaken in a cooperative effort by all of the relevant USA interests. The evidence discloses that CASA does not have the laboratory facilities, or the technical staff to perform such a task. CASA submits that a recommendation should be made to the effect that the engine operating procedures – in particular, the power and mixture settings – set out in the various versions of the Pilot Operating Handbooks and Flight Manuals for Piper Chieftain aircraft be reviewed with the object of ensuring (a) accuracy of the detonation limiting conditions and (b) clarity of all engine operating procedures.'

15.20. I recommend that engine operating procedures set out in the various versions of the Pilot Operating Handbooks and Flight Manuals for Piper Chieftain Aircraft be reviewed with the object of ensuring:

(a) accuracy of the detonation limiting conditions; and

(b) clarity of all engine operating procedures.

15.21. International Cooperation

Much was made by Mr Cavenagh in his evidence about the fact that Australia is a signatory to the Chicago Convention on International Civil Aviation and that investigative agencies cooperate and exchange information about aircraft incidents. This is a very desirable thing.

15.22. Unfortunately, in this case it would appear that this cooperation ceased as soon as it became apparent that there might be litigation in the United States of America. I was told that a number of requests for information, by both CASA and the ATSB, to their American counterparts were not successful once this fact became apparent. As a result of this, it is abundantly clear that the ATSB had little information about other

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crankshaft failures in the United States with which to compare this incident. The ATSB may have led the authorities in the United States to believe that this incident was unrelated to the United States failures. The February 2002 briefing by the FAA, reported that the Australian incident had been attributed to engine detonation due to engine leaning procedures adopted by several Australian operators.

15.23. In my opinion, this lack of free information exchange may well have seriously hampered the ATSB in understanding what happened here, causing them to take a path of inquiry different to that taken by the United States investigators.

15.24. I therefore recommend that CASA and the ATSB consider how lines of communication could be improved so that communication continues to flow even in circumstances where litigation might be threatened or instigated.

15.25. Cockpit Flight Recorders / On-Board Recorder Systems

It can be seen from these findings that the ascertainment of the precise failure sequence of the two engines in MZK on 31 May 2000 has been a difficult task because of the paucity of evidence about what happened during the flight.

15.26. In my opinion, it is highly unsatisfactory that there should be so much uncertainty in the case of a Regular Passenger Transport (RPT) flight. Seven of the eight people who died during Flight 904 on 31 May 2000 were fare-paying passengers, and Mr Mackiewicz was a fully qualified commercial pilot.

15.27. One way to improve the fact-finding capabilities of investigators examining an incident such as this would be to require that all aircraft involved in conveyance of passengers for payment, or at least all aircraft engaged in RPT, should carry a Cockpit Flight Recorder, also known as an On-Board Recorder (OBR).

15.28. I note that these instruments were recently considered by the State Coroner for Western Australia, Mr Alastair Hope, during an inquest into the deaths of eight people in September 2000 as a result of an aircraft accident, known colloquially as the ‘Ghost Flight’. An aircraft bound for the Western Australian goldfields lost pressurisation, and continued to fly on autopilot, with the occupants incapacitated or dead, until it ran out of fuel and crashed in Northern Queensland.

(Signed)

15.29. I agree with Mr Hope's comments at pages 68-70 of his finding, which are reproduced below, and find that they are also apt in the present case. He said:

> 'While I accept that there are a number of issues involved in consideration of the use of aircraft recorders, it is obvious from the present case that there are potential safety benefits which could be derived from having such devices installed in aircraft such as the one in question.
>
> While I agree that information at the Inquest would not enable me to make any observations about how such aircraft recorders could be made crashworthy, the cost of installation of such recorders and possible problems which might occur from the use of such recording systems in the conditions found in many smaller aircraft, there was evidence given at the Inquest to the effect that there have been recent developments in relation to such recording devices and there are obvious potential safety benefits, to be derived from their use.
>
> I recommend that CASA examine whether the potential safety benefits from devices such as those that monitor and record aircraft systems and operation are sufficient to warrant them being required in general aviation aircraft used in air transport operations. If such a system is to be considered by CASA, then CASA should determine if one of the matters to be monitored by such a system should be the internal cabin pressure of such aircraft.'

I note that CASA has already considered Mr Hope's recommendation, which was adopted by the ATSB as Recommendation R20020149. In a letter to the ATSB, dated 21 November 2002 (Exhibit C232), Mr Bruce Gemmell, the Deputy Director of Aviation Safety at CASA said:

> 'These modifications are usually unique to each aircraft. As CASA has shown from its research, they are expensive to develop, and expensive to install and maintain.
>
> Moreover, the benefits of low cost recorders are also limited because they:
>
> - are not designed for aircraft use and therefore may emit undesirable radiation that can interfere with the aircraft electronics;
> - are not crashworthy and may not survive a substantial crash and subsequent fire; and
> - have limited capacity in terms of data channels which can be recorded, in that the data that may be important to an investigation cannot be recorded.' (Exhibit C232, p2)

15.30. It seems to me that this matter should be the subject of continuing consideration. Technology such as this develops quickly, particularly if it is stimulated by interest from regulatory bodies such as CASA. I do not understand the reluctance of CASA, exemplified in Mr Gemmell's letter, to enter an area where no other regulatory body has entered.

(Signed)

15.31. I am convinced that the fitment of an OBR would enhance our understanding of these tragedies, and go a long way towards preventing further accidents.

15.32. I recommend that CASA consider how the development of On-Board Recorders suitable for use in light commercial aircraft might be facilitated. Should fitment of On-Board Recorders in these aircraft become feasible, I further recommend that their use be mandatory in the carriage of passengers for payment, or at least in RPT operations.

15.33. Self-deploying Emergency Locator Transmitters

I have described the fact that the pilot of VH-FMC heard an emission from an Emergency Locator Transmitter (ELT) at about 7:06pm on 31 May 2000.

15.34. An ELT is an instrument fitted to an aircraft which is activated on impact, and which emits a radio signal which enables the aircraft to be located by triangulation. Unfortunately, the signal only lasted for about 20 seconds, not long enough to allow it to be located. It seems likely that the signal was from MZK, and that it ceased when the aircraft became submerged.

15.35. I was told that once this type of ELT is submerged in water, it will continue to operate, but the radio wave will not be transmitted through water. For such an instrument to be useful after an aircraft has ditched, and the aircraft has submerged, it must either be able to transmit under water, or detach from the aircraft so that it floats on the surface of the water. The former is clearly not possible as quite different radio frequencies are involved (see the evidence of Sargeant Darryl Wright at T594).

15.36. I was told by Mr John Young, an Operations Manager employed by AusSAR, that he had made inquiries among his profession. He has ascertained that the United States Coast Guard and an Australian helicopter company have both experimented with automatically releasing beacons, but this had not progressed because of concerns about accidental release of the beacon during flight (T468).

15.37. The statement of Mr Lance Thorogood, the Senior Airworthiness Officer, Avionics, in the Technical Specialist Section of CASA includes the following information:

> 'Sonar Devices
>
> Standard ELT's transmitting a radio signal, if undamaged, will continue to transmit even whilst completely submerged. However, due to the properties of water, the signal would not be detected by any receiver.

(Signed)

> Devices are available which send a sonar signal or “ping” in situations where the device is completely submerged. The sonar device produces a low frequency sound signal that can be detected by ships equipped with a receiver sonobuoy that is trailed in the water to trace the source of the sonar signal. This type of device will not transmit any radio frequency and is only of use where the device is submerged. CASA does not regard it as a practical alternative to the current ELT’s. CASA is not aware of such devices being mandated by any other aviation regulatory authority.
>
> Detachable ELT’s
>
> DRS Flight Safety and Communication Pty Limited is the only organisation known to CASA to manufacture ELT’s which are deployed from the aircraft, either by way of an explosive or spring action, on impact. This type of ELT will only deploy if the structure housing the ELT has not been distorted by the impact. This type of ELT is designed to float, should it be deployed when the aircraft hits the water. The cost of such an ELT is in the range of $10,000 to $12,000 plus expenses in relation to fitting the device to the aircraft. Transport Canada has authorised (but not mandated) the use of this type of ELT on civil helicopters only. CASA is not aware of such devices being mandated by any other aviation regulatory authority.' (Exhibit C191, p4)

Once again this evidences a reluctance by CASA to enter a field where no other regulatory body has gone before.

15.38. I note that the RAAF have fitted self-deploying ELT’s to its Orion aircraft. These devices will activate on impact, if battery power ceases for a given time, or if they are manually activated (Ferguson T365-67).

15.39. Although a self-deploying ELT may not have saved the occupants of MZK, this is the third aircraft mishap in Spencer Gulf in the last 10 years, and in the two other cases, earlier location of the aircraft would have significantly increased the chances of survival of the people who died (see Ghersi, Inquest No. 29/96 and Urquhart, Inquest No. 26/94). In my opinion, those circumstances are sufficiently ‘similar’, for the purposes of section 25(2) of the Coroners Act, 1975, to warrant a recommendation.

15.40. In my opinion, more could be done to develop a self-deploying system which would obviate the present difficulties with static ELT’s, and portables.

15.41. I recommend that the ATSB and CASA undertake a research program to ascertain whether it is feasible to fit a self-deploying ELT system to all aircraft engaged in carriage of fare-paying passengers, whether by RPT or charter operations, over water. If it is feasible, the use of such instruments in those circumstances should be mandatory.

(Signed)

15.42. Lifejackets

Having regard to the evidence of Dr Brock, it seems clear that even if MZK had been required to carry lifejackets on 31 May 2000, they would not have assisted anyone on board that night (see Exhibit C168, p8).

15.43. Dr Brock pointed out that lifejackets would have been important if MZK had ditched without major damage, did not sink quickly, and one or more of the occupants could have exited the aircraft with lifejackets and inflated them outside. I refer to the information in paragraphs 3.11-3.12 herein, where such cases have been recorded. Both Mr Ghersi and Dr Urquhart managed to exit their aircraft before it sank, and if they had lifejackets their chances of survival would have been better.

15.44. Dr Brock pointed out that if a lifejacket had been inflated inside the aircraft, it would have constituted a 'menace' (T1223-24).

15.45. I was advised by Mr Harvey, counsel for CASA, that as from 1 July 2003 it will be compulsory for aircraft carrying passengers for payment to be equipped with a lifejacket or flotation device for each passenger 'on all flights where the take-off or approach path is so disposed over water that in the event of a mishap occurring during the departure or arrival, it's reasonably possible the aircraft would be forced to land on to water' (T2945).

15.46. While this is a step in the right direction, I agree with the ATSB's recommendation R20000249:

> 'The Australian Transport Safety Bureau recommends that the Civil Aviation Safety Authority ensure that Civil Aviation Orders provide for adequate emergency and life saving equipment for the protection of fare-paying passengers during over-water flights where an aircraft is operating beyond the distance from which it could reach the shore with all engines inoperative.' (Exhibit C97, p123)

15.47. I recommend that CASA amend the Civil Aviation Orders to make it mandatory that aircraft should carry lifejackets and/or a life-raft for the protection of fare-paying passengers whenever the aircraft is operating beyond the distance from which it could reach the shore with all engines inoperative.

15.48. Multi-probe Cylinder Head Temperature (CHT) Gauges and Knock Sensors

It was common ground at the inquest that the CHT gauges on MZK (depicted in Exhibit C97, p14) are connected to only one probe in the engine, usually in the No.6 cylinder, which should be the hottest.

(Signed)

15.49. Mr Braly told me that in his opinion, it was far more satisfactory to have an engine monitoring system which monitors the temperature of all six cylinders, as well as the exhaust gas temperature for all six cylinders and the turbine inlet temperature as well. The system he demonstrated scans all cylinders sequentially, and an alarm can be programmed to sound if an engine parameter exceeds a set value (T3154).

15.50. The same instrument can also monitor the air temperature, fuel flow rate, voltage in the electrical system, oil temperature, all of which are important engine parameters, and in relation to all of which the traditional gauges are somewhat primitive and in some cases inaccurate.

15.51. Mr Braly said that it was possible to detect engine trouble very early in the piece using this instrument, and avoid catastrophic engine damage initiated by, say, a failed spark plug. He demonstrated, using a PowerPoint display, an actual event where such damage was averted this way (T3161-3173).

15.52. There was a division of opinion, though, as to whether such instruments should be retro-fitted to older aircraft such as MZK. Mr Heyne thought it might make the pilots job more complex (T296), and Mr Thompson (T3833) and Mr Beattie (T1954-55) referred to 'information overload'. Messrs Kuch (T1418), Reymond (T1600) and Usher (T1650) disagreed. Mr Kym Brougham thought that fitting such gauges would not be useful so long as regulators continued to insist that the original gauges be the first point of reference (T2324-25).

15.53. Mr Sharp thought that such instruments would be useful so long as they are not used to run the engine close to its limits (T2396).

15.54. Mr Lyons, from CASA, said:

> 'CASA has no evidence that requiring multi-probe gauges to be installed on piston engine aircraft is necessary.' (T4415)

15.55. It was also suggested that 'knock sensors' could be installed in aircraft engines of this type, to detect 'knock' or detonation. (See the evidence of Mr Murphy T2153-54, Mr Brougham T2325-6 and Dr Zockel T3463). Modern automotive engines are fitted with such devices, which are connected to the electronic engine management system. When the sensor detects detonation, it automatically adjusts the timing to prevent this. Of course, aircraft like MZK do not have an electronic engine management system, the engine is managed by the pilot.

15.56. Mr Lyons also took a conservative view of knock sensors. He said:

> 'In the history of piston aviation there's never been any real evidence to suggest that knock sensors would be of benefit. Going back to when airliners were piston engine powered and running under extreme load, there was instrumentation provided to the flight engineer to be able to monitor those loads, but in the current generation of piston engines, the loading - provided the engine is operated conservatively - doesn't require such instrumentation to ensure the engine remains reliable.' (T4416)

15.57. I do not have enough information before me to make a formal recommendation on either of these areas. I cannot be satisfied that the use of a multi-probe gauge or a knock sensor would have prevented this incident. It does seem surprising that these engines have relatively primitive manual management systems, compared with the system to be found in even the most inexpensive car these days.

15.58. Mr Lyons' conservatism is understandable, but the evidence before me is quite cogent, and suggests that the fitment of multi-probe gauges would be likely to improve the pilot's ability to manage the engines appropriately. I note the offer made by Mr McIlwaine SC, on behalf of the ATSB, to assist in the formulation of a recommendation to CASA. I am grateful for the offer, but since I am unable to make the recommendation, for the reasons expressed, I will leave it for the ATSB to take up.

15.59. Oil testing

Mr Braly suggested that if the bearings had failed progressively over the 50-70 flights before 31 May 2000, and this had not been detected by a visual examination of the oil screens and filters, as I have found it was not, then it may have been detected by a spectrographic examination of the oil by a laboratory. He said that he had been doing that since about 1991 (T3300).

15.60. This also seems to be an idea that should be considered by the ATSB with a view to making a recommendation to CASA. I am not in a position to make a recommendation that it be done, because I am not satisfied that, in this particular case, the failure sequence of the engine involved progressive bearing failure. However, I believe that in the general course of aviation, it is a matter that deserves further consideration by the regulator.

(Signed)

15.61. Summary of Recommendations

Pursuant to section 25(2) of the Coroners Act, 1975, I recommend that:

15.62. Engine operating procedures set out in the various versions of the Pilot Operating Handbooks and Flight Manuals for Piper Chieftain Aircraft be reviewed with the object of ensuring:

(a) accuracy of the detonation limiting conditions; and

(b) clarity of all engine operating procedures.

15.63. CASA and the ATSB consider how lines of communication could be improved so that communication continues to flow even in circumstances where litigation might be threatened.

15.64. CASA consider how the development of On-Board Recorders suitable for use in light commercial aircraft might be facilitated. Should fitment of On-Board Recorders in these aircraft become feasible, I further recommend that their use be mandatory in the carriage of passengers for payment, or at least in RPT operations.

15.65. The ATSB and CASA undertake a research program to ascertain whether it is feasible to fit a self-deploying ELT system to all aircraft engaged in carriage of fare-paying passengers, whether by RPT or charter operations, over water. If it is feasible, the use of such instruments in those circumstances should be mandatory.

15.66. CASA amend the Civil Aviation Orders to make it mandatory that aircraft should carry lifejackets and/or a life-raft for the protection of fare-paying passengers whenever the aircraft is operating beyond the distance from which it could reach the shore with all engines inoperative.

Key Words: Aircraft Accident; Search and Rescue; Aircraft Engine Failure

In witness whereof the said Coroner has hereunto set and subscribed

his hand and Seal the 24th day of July, 2003.

Coroner

Inquest Number 21/2002

(Signed)