J10/2/7132	A99-141

SOUTH AFRICAN CIVIL AVIATION AUTHORITY

ACCIDENT REPORT EXECUTIVE SUMMARY

Date of Accident	06 December 1999	**Time of Accident**		0506z	
Aircraft Registration	**ZS-OJY**	**Type of Aircraft**		**Piper PA31-350**	
Pilot-in-command Licence Type		Commercial		**Licence Valid**	Yes
Pilot-in-command Flying Experience		Total Flying Hours	1444:55	Total Hours on Type	445:25
Type of Operation		International Charter flight			
Last point of departure		Rand Airport			
Next point of intended landing		Oranjemund in Namibia			

Location of the accident site with reference to easily defined geographical points (plus GPS readings if possible)

To the right of the extended centre line of RWY 29 about 2 nm west of Rand Airport (S26°14,43' E028°07,05').

Meteorological Information	Weather was fine.				
Number of people on board	1 + 9	**No. of people injured**	Nil	**No. of people killed**	1 + 9

Synopsis

The aircraft took-off from Rand Airport on a commercial chartered flight to Oranjemund in Namibia. Shortly after take-off the pilot reported an engine defect and the aircraft crashed about two minutes after take-off. The pilot and his nine passengers were all killed in the accident. The post-impact fire destroyed the aircraft.

During the investigation it was found that the right-hand engine lost power due to a mechanical defect. The investigation established that the aircraft was overloaded, and in its “loaded condition” was unable to climb with only one engine fully functional.

Several factors relating to the documentation and management actions of the charter operator and those of the CAA as the regulator were a source of concern during the investigation and are addressed in this report.

Probable Cause

The precipitative cause of this accident was the failure of the exhaust pipe segment, which caused the right–hand engine to lose power/fail. The aircraft was also overloaded and consequently was unable to maintain altitude.

AIRCRAFT ACCIDENT REPORT

Ref : J10/2/7132

Name of Owner/Operator : Flightline Charter Services CC
Manufacturer : Piper
Model : PA31-350
Nationality : South African
Registration Marks : ZS-OJY
Place : To the right of the extended centre line of RWY 29 about 2 nm from Rand Airport (S26°14,4 3' E028°07,05').
Date : 6 December 1999
Time : 0506z

All times given in this report are Co-ordinated Universal Time (UTC). South African Standard Time is UTC plus 2 hours.

Disclaimer:

This report is given without prejudice to the rights of the CAA, which are reserved.

Purpose of the Investigation :

In terms of Regulation 12.03.1 of the Civil Aviation Regulation,1997, this report was compiled in the interest of the promotion of aviation safety and the reduction of the risk of aviation accident or incidents and **not to establish legal liability**.

1. FACTUAL INFORMATION.

1.1 History of flight.

1.1.1 The charter operator was involved in a weekly operation to transport computer programmers and training staff, from a Johannesburg company, from Rand Airport to Oranjemund in Namibia. The outward leg of the flights to Oranjemund took place on the Monday morning and the pilot and aircraft stayed at Oranjemund for the week. The return flight to Johannesburg usually took place on the Friday afternoon.

1.1.2 On the morning of the accident flight the set time of departure was 0500z. The passengers were assisted through the process of passport control, boarding and settling in by the operator's staff. The baggage was put next to the aircraft. According to a witness the pilot carried out the loading of the baggage.

1.1.3 An instrument flight plan was filed and the pilot obtained departure clearance before the aircraft was taxied to the holding point. According to the air traffic controller, the take-off run was normal for this type of aircraft. Shortly after take-off the pilot declared an engine failure and requested to be routed back to land on the runway. Seconds later the pilot communicated they were going to crash.

1.1.4 Several witnesses stated that the aircraft was very low when it passed over the highway close to the accident site. One of the witnesses stated that he noticed the right-hand engine stopped and he could see the blades of the propeller.

1.1.5 The fire fighting services were alerted. It was apparent by the smoke that the aircraft crashed on an extended line of Runway 29.

1.1.6 The accident took place at 0506z in daylight conditions.

1.2 Injuries to persons.

Injuries	Pilot	Crew	Pass.	Other
Fatal	1	-	9	-
Serious	-	-	-	-
Minor	-	-	-	-
None	-	-	-	-

1.3 Damage to aircraft.

1.3.1 The aircraft was totally destroyed during the post-impact fire.

1.4 Other damage.

1.4.1 The damage to the environment was limited to the fire damage caused by the post-impact fire, three small trees that were broken off at ground level, and the small amounts of pollution in the stream of water.

1.5 Personnel information.

1.5.1 The following information was obtained about the pilot:

Nationality		South African			
Licence No	CA26104	Gender	Male	Age	27
Licence valid		Yes	Type Endorsed	Yes	
Ratings		Instrument rating			
Medical Expiry Date		31 January 2000			
Restrictions		None			
Previous Accidents		None, but one airspace violation incident.			

1.5.2 The pilot's logbook was recovered from the wreckage in a fairly damaged state due to fire and water exposure. The pilot's logbook was dried out and it was determined that the logbook was up to date to 22 November 1999. A return flight from Oranjemund to Rand Airport on 26 November 1999 of 4:10 hours was not entered. The following table reflects his flying experience according to this information:

Total Hours	1444:55 hours
Total Past 90 Days	127:05 hours
Total on Type Past 90 Days	104:15 hours
Total on Type	445:25 hours

1.5.3 A letter of acknowledgement, dated 23/06/1997, from the pilot's previous employer stated that he had a previous experience of a partial engine failure after take-off when he flew a Cessna 404. The letter stated the following:

> "*Then (and this was a nasty story) on take-off from Faranah: Partial engine failure on left engine. A decision had to be made within seconds whether to feather or not, the engine was backfiring and shaking, aircraft was busy going down, with no place to force land. Afterwards, whilst re-evaluating, it was realised that the odds were grossly against them. If J.D. elected to feather – because they were so low, they would have crashed. If the power did not come back on; literally at the last second, they would have crashed. I can only believe, that it was very skillful flying, cool crisis control on J.D's behalf and above all, the grace of God that the power came back on at the last moment that averted a major accident.*"

1.5.4 The pilot was the holder of a Commercial Pilot Licence (CPL) with an instrument rating. According to his CAA pilot file, he completed his theoretical examinations as a requirement to obtain his Airline Transport Pilot Licence (ATP) on 23 April 1999 (however, he still required some additional flying hours and a flight test to obtain his ATP).

1.6 Aircraft information.

1.6.1 The instrument panel was totally destroyed during the accident and the post-impact fire. It was thus impossible to determine the Hobbsmeter reading. The flight folio was recovered from the wreckage, but was damaged by the post-impact fire. After a drying out period it was possible to read the last entries into this document. These entries were made during the last mandatory periodic inspection on 23 September 1999. From this date onward no entries were made in the aircraft's flight folio as per requirement of the Civil Aviation Regulations, 1997 Part 91.03.5 relating to Flight Folio's.

1.6.2 Enquiries at Air Traffic and Navigational Services indicated that the aircraft undertook several flights during the time between the mandatory periodic inspection and the day of the accident. When the movement entries of the Air Traffic and Navigational Services were correlated with the logbook entries of the two pilots that usually flew the aircraft, two flights were not accounted for in the logbooks of these two pilots, one being a flight to Maputo and the other a local flight at Rand Airport. The time logged by one of the pilots for a previous Maputo flight was 3.4 hours and the Air Traffic Controller at Rand Airport determined that the local flight at Rand Airport was a total of 14 minutes. When all these times were totalled, the total time since the mandatory periodic inspection amounts to 101:45 airframe hours.

1.6.3 The time logged by the Hobbsmeter (which is widely used in the industry to record airframe hours) would most probably be less than this figure. The Hobbsmeters are usually connected to either the oil pressure switch on one of the engines, the landing gear switch or in this case a pressure switch activated by the total pressure build-up during the take-off roll. Wiring diagrams (Figure 11-79 Starter and Hourmeter) in the Service Manual of the aircraft indicate that the hourmeter should be activated by a pressure switch, which in the manual's case is usually the oil pressure switch. A close estimate would be 90 % of the total time. This would then amount to 91.58 hours. This value will now be used to determine the total airframe time at the time of the accident. It should be kept in mind that this way of recording flight time is not as defined in the Civil Aviation Regulations (1997, Part 1). Flight time is defined as *the total time occupied in flight together with the time occupied from the moment the aircraft first moves under its own power for the purposes of taking off until the moment it comes to rest at the end of the flight.* There should also be no difference between the times that the pilot logs in his/her logbook in relation to the times that are recorded in the aircraft's flight folio.

1.6.4 A further point to be considered was that according to the TV2/72 notification form sent by the aircraft maintenance organisation to the CAA after mandatory periodic inspections, the aircraft had overflown its previous mandatory periodic inspection time by 3.75 hours. The mandatory periodic inspection was due at 8227.05 airframe hours, but was only carried out at 8230.8 airframe hours. The times recorded in the flight folio for the last two flights prior to the previous mandatory periodic inspection were on 10 September 1999. They included a flight to Vilankulo, Mozambique and return. The outward leg to Vilankulo was recorded as 2.7 hours to give a total of 8228.1 airframe hours. At this time the aircraft has already overflown the mandatory periodic inspection time by about one hour. The flight back from Vilankulo to Rand Airport was another 2.7 hours to give a total of 8230.8 airframe hours. Thus the last flight conducted was non-compliant with regulatory prescriptions because the Certificate of Maintenance Release became invalid after 8227.05 airframe hours and rendered the Certificate of Airworthiness invalid.

1.6.5 In contrast to the 2.7 and 2.7 hours (a total of 5.4 hours) recorded in the flight folio for these flights to Vilankulo and back, the deceased pilot logged in his pilot's logbook a total of 6.10 hours. This could be interpreted that the pilot had either overbooked his flying hours or has booked fewer hours in the flight folio.

1.6.6 The hours that the aircraft had exceeded the mandatory periodic inspection time by, were not indicated on the TV2/72 form in the space provided for recording the hours that the aircraft has overflown the required 100 hours.

1.6.7 The time that the aircraft had overflown its mandatory periodic inspection are usually subtracted from the next 100 hours to the next mandatory periodic inspection. The certificate of maintenance release should have been certified for 96.25 hours instead of 100 hours as usual by the Aircraft Maintenance Organisation. The implication of this 3.75 hours was that the aircraft would have exceeded its time to the next mandatory periodic inspection during the flights to Oranjemund and back, which ended up as the accident flight.

1.6.8 If it is considered that the pilots used the Hobbsmeter readings, the time from the last mandatory periodic inspection was calculated as 91.58 hours and with the 3.75 hours it came to 95.33 hours. The flight to Oranjemund and back was on the average about 8 hours according to the pilots' logbooks, which suggests that the aircraft would have exceeded its allowable 100 hours to the mandatory periodic inspection by about 3.33 hours.

1.6.9 The following information was obtained about the aircraft (hours for engines and propellers are calculated with the 91.58 hours as basis):

Airframe :

Type	PA31-350 Ser. No. 31-7405210	
Manufacturer	Piper	
Date of Manufacture	1974	
Total Airframe Hours (At time of Accident)	8422.38 hours	
Last MPI (Date & Hours)	23 Sep. 1999	8330.8 hours
Hours since Last MPI	91.58 hours	
C of A (Issue Date)	16 April 1999	
C of R (Issue Date) (Present owner)	05 May 1999	
Operating Categories	Standard	

Engine :

No. 1 (Left-hand)

Type	Lycoming TIO-540-J2BD Ser. L6729-61A
Hours since New	6236.22 hours
Hours since Overhaul	876.13 hours

No. 2 (Right-hand)

Type	Lycoming LTIO-540-J2BD Ser. L-2037-68A
Hours since New	4242.08 hours
Hours since Overhaul	876.13 hours

Propeller :

No. 1 (Left-hand)

Type	Hartzell HC E3YR-2A Ser. No. DJ 10737A
Hours since New	Unknown
Hours since Overhaul	564.18 hours

No. 2 (Right-hand) - See next page:

Type	Hartzell HC E3YR-2AL Ser. No. DJ 10738A
Hours since New	Unknown
Hours since Overhaul	564.18 hours

1.6.10 According to the logbook of the Right-hand engine and the work-pack of the aircraft maintenance organisation, work was carried out on the turbocharger system of this engine after the last mandatory periodic inspection was certified on 23 September 1999. The fixed density controller was removed on 30 September 1999, overhauled and tested. On 1 October 1999 the component was refitted and a ground run was performed at which time the boost of the engine was set. On the same day the turbocharger was removed and handed in for an overhaul. On 5 October 1999 the turbocharger was refitted and a ground run was carried out. No further work was logged on this turbocharger system.

1.6.11 The aircraft was fitted with a vortex generator kit according to a FAA Supplementary Type Certificate No. SA5796NM. An entry in an old logbook of the aircraft indicates that this kit was fitted on 13 May 1994. When this kit is fitted to an aircraft the Maximum Ramp Weight may be increased to 7295 lbs. During the airworthiness inspections of the aircraft when it was imported into South Africa (in April 1999), this kit was not included on the equipment checklist. Neither was the increased ramp weight considered during the performance test flight. The aircraft was certified as a standard 7000 lbs. Maximum Take-off Mass or 7045 lbs. Maximum Ramp Mass aircraft according to the CAA documentation. When asked about this discrepancy, the operator/owner of the aircraft produced technical specifications for a different vortex generator kit, which increases the Maximum Ramp Mass of the aircraft to 7448 lbs. However, that was not the kit fitted to the aircraft.

1.6.12 The Airplane Flight Manual Supplement related to the performance of the aircraft when fitted with the vortex generator kit (the kit fitted to the aircraft) was related to the original Pilot's Operating Handbook of the aircraft. In both documents, the single engine climb speed is stated as 106 Knots Indicated Airspeed (KIAS) or better known as the Blue Line Speed. The difference is noted in the Minimum Single-Engine Control Speed (V_{mca}) where the original speed is indicated as 76 KIAS, but with the vortex generator kit fitted it is reduced to 72 KIAS.

1.6.13 As much baggage as possible was recovered from the accident scene. The area where each item of baggage was found was noted. The baggage was severely damaged by the post-impact fire and some of it was also very wet. It was laid out in a secure place to dry out for four days before it was weighed on a calibrated scale of the South African Bureau of Standards. The contents of a cooler box with cool drinks and other beverages were recovered in the rear area of wreckage. The cooler box was totally destroyed. These items were weighed separately and it weighed 9,36 kg. (20.64 lbs.). A similar cooler box and contents were weighed and it was found to be 22 lbs.

1.6.14 The masses of the pilot and the passengers were obtained from previous medical records and estimations by colleagues. According to their colleagues the passengers used to sit in the same seats in the aircraft during the flights. This facilitated the calculations of the mass and balance situation of the aircraft.

1.6.15 The aircraft was weighed on 9 April 1999. During the calculation of the aircraft empty mass, the mass from the scale readings was determined as 4594.385 lbs. When this figure was carried over to the bottom of the mass determination report page an error occurred. The empty mass at the bottom of the page was indicated as 4394.385 lbs., a full 200 lbs. less than the actual mass. No copy of the Mass and Balance Data report (TV 2/9) was found on the CAA Aircraft File or were found in the aircraft documentation recovered. The Mass and Balance Data report (TV 2/9) was not a requirement any more according to the Civil Aviation Regulations 1997.

1.6.16 A further issue to be considered is that the aircraft was fitted with a Nacelle Fuel System. This was not noted on the approved equipment checklist. The fuel attendant on the morning of the flight stated that he uplifted the aircraft to full capacity with fuel at six fuelling points. The fuel capacity of the aircraft with this fuel system included is increased to a total of 236 US gallons (useable).

1.6.17 Considering the above evidence, the following mass and balance computation was produced for the aircraft for the accident flight (the standard maximum ramp mass was considered and the correct empty mass of the aircraft):

	Mass (lbs)	Arm (inches)	Moment
Basic aircraft	4594.385	124.08	570071.29
Pilot and passenger	171.96 + 242.51	95	39374.65
Passengers in seats 3 and 4	130.07 + 138.69	132	35476.32
Passengers in seats 5 and 6	110.23 + 138.69	163.5	40698.42
Passengers in seats 7 and 8	119.05 + 110.23	195	44709.6
Passenger in seat 9	143.3	229	32815.7
Passenger in seat 10	143.3	247	35395.1
Forward baggage	266.61	19	5065.59
Wing nacelle baggage	83.69	192	16068.48
Rear cool drinks	22	255	5610
Inboard fuel	106 gall. = 636 lbs.	126.8	80644.8
Outboard fuel	76 gall. = 456 lbs.	148	67488
Nacelle fuel	54 gall. = 324 lbs.	142.8	46267.2
TOTAL	**7830.715**		**1019685.15**

$$\frac{1019685.15}{7830.715} = 130.22 \, inches \, aft \, of \, datum$$

Centre of gravity position:

1.6.18 The Maximum Certified Ramp Mass of the standard aircraft was 7045 lbs. and a centre of gravity range of 126 to 135 inches behind the datum. According to this scenario the aircraft was thus overloaded by 785.715 lbs. (more than 11%), but the centre of gravity position was within limits.

1.6.19 If a scenario is considered where the unapproved vortex generator kit's Maximum Ramp Mass (indicated as 7295 lbs.) is assumed as the effective maximum ramp mass, then the aircraft was still overloaded by 535.715 lbs (more than 7,6%).

1.6.20 A copy of the load sheet for the accident flight was requested from the operator. He produced a computer-printed load sheet (not signed by the pilot as required by the Civil Aviation Regulations, 1997, Part 91.02.7), with a different aircraft registration number and no baggage stored in the wing nacelle areas. The forward baggage indicated 70 lbs., but the total mass of all the passengers were indicated as 232 lbs. more than the actual mass of the passengers. No nacelle fuel tanks are indicated on this sheet and this sheet does not conform to the prescribed minimum contents of a load and trim sheet as per SA-CATS-OPS 135-70 (Also refer the Civil Aviation Regulations Part 135.04.9). No evidence was found of the pilot or operator performing accurate load and trim calculations for this flight, as required by the above Civil Aviation Regulation.

1.6.21 During interviews with the investigator-in-charge, three witnesses (the pilot's sister, a friend and his fiancé) stated that the pilot had expressed concerns to them about the conditions that he had to fly under. He mentioned to them taking-off overloaded and sometimes on runways in poor condition. His sister stated that she heard him discussing these concerns over his cellphone with one of his colleagues at the operator one afternoon. According to the operator's management plan, the pilot was the Aviation Safety Officer. It seems that although he was concerned about the conditions he did not, or was unable to take action about it (refer to 1.17.1.3).

1.6.22 The Flight Performance test flight of the aircraft was carried out by the owner/operator. On the climb test report he indicated that the aircraft climbed with the right-hand engine "out" at the following rate:

See next page

Time (min:sec).	Altitude (feet)	Rate of climb (feet per min.)	Outside Air Temp. (℃)	Manifold Press. (inches)
0:00	6000	-	16	44
0:30	6500	1000	?	44
1:00	6800	600	13	44
1:30	7000	400	11	44
2:00	7200	400	10	44
2:30	7500	600	9	44
3:00	7700	400	8	44
3:30	7900	400	8	43
4:00	8200	600	7	43
4:30	8400	400	6	43
5:00	8700	600	5	43

1.6.23 If the average rate of climb is derived from the data provided in the above table it appears that the aircraft maintained an average rate of climb of 540 feet per minute. If the performance figures are related to the Single Engine Climb performance chart in the Pilot's Operating Handbook of the aircraft, the rate of climb should be approximately 105 feet per minute. This discrepancy would indicate significant anomalies in the flight test profile, which should have been identified during the certification of the aircraft by the airworthiness inspector, when it was imported in April 1999. Usually a graph is drawn and the rate of climb is calculated from this data, but no such graph was attached to the performance flight test report. It was indicated on the test flight report that the take-off mass of the aircraft was 7000 lbs. and the best rate of climb speed for specific configuration was 130 Miles Per Hour (113 knots). According to the performance charts of the aircraft in the Pilot's Operating Handbook, the single engine rate of climb speed at 7000 lbs. is 106 knots.

1.6.24 Operators of Piper Chieftain aircraft were contacted about the single engine climb performance of the aircraft. They agreed that the aircraft would not climb at maximum mass in the high-altitude and temperature conditions of Rand Airport, if the speed were not maintained at 106 knots (blue line speed). Any speed lower than this speed or unbalanced flight is very critical to the climb performance of the aircraft.

1.6.25 The checklist used during the airworthiness inspection of the aircraft (signed by the chief inspector of the aircraft maintenance organisation) requires confirmation that modifications made were carried over into the aircraft's logbooks. This point was marked as completed. However, when the new logbooks of the aircraft were inspected it was determined that the standard published logbooks do not make provision for recording such modifications, and noted that the modifications were not recorded. Provision is made for records of Airworthiness Directives, Service Bulletins, etc. in the logbooks.

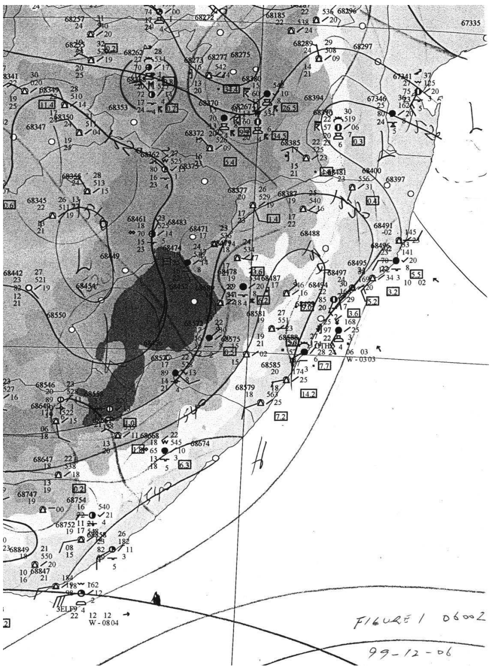
1.6.26 A Pilot's Operating Handbook for this type of aircraft was consulted and under the section dealing with EMERGENCY PROCEDURES the ENGINE INOPERATIVE PROCEDURES were reviewed. The relevant sub-heading in this case is SECURING PROCEDURE (FEATHERING PROCEDURE). This procedure entails closing the throttle, feathering the propeller (1000 RPM min.) and setting the mixture to the IDLE CUT-OFF position. Following actions include switching off fuel, magnetos, etc. Under the section ENGINE FAILURE DURING CLIMB the handbook is very specific in that it states that airspeed must be maintained at 106 KIAS, directional control should be maintained, identify and verify the inoperative engine and complete the engine securing procedure. The final point is to land as soon as practical at the nearest airport.

1.6.27 During the on-site investigation it was observed that the right-hand propeller was feathered. This would suggest that the pilot had followed these procedures after he encountered the right-hand engine failure, but due to the very limited time at hand (about 1.5 minutes from take-off to the accident) he was most probably unable to troubleshoot the possible defect of the failed engine.

1.7 Meteorological information.

1.7.1 The following meteorological information was obtained from the weather report and the air traffic control recording:

Wind direction	310°	Wind speed	13 knots	Visibility	> 10km
Temperature	17℃	Cloud cover	Few/CB	Cloud base	040 AGL
Dew point	16℃	QNH	1022 hPa		



The investigators arrived at the scene of the accident about an hour after the accident occurred and the weather was clear with no clouds and good visibility. The temperature was ob... between 15 and 20°C and the surface...

JHB area

The official weather report from the South African Weather bureau indicated the following:

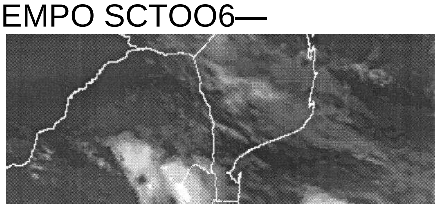
1.7.3.1 SURFACE OBSERVATIONS

A surface trough extended from Gauteng to Maputo (in Mozambique) with warm and moist tropical air in circulation to the east of it and cooler maritime air from the south-west (figure 1). Thundershowers and showers, which occurred along this line during the night, were in the final dissipating stage at 0500 UTC (07:00 SAST).

The nearest surface observation was at Johannesburg international Airport:-

FAJS 060430Z 34009KT 9999 FEWO4OCB SCTOSO 16/16 Q1022 TEMPO SCTOO6=

FAJS 060500Z 34010KT 9999 FEWO4OCB SCTO8O 17/16 Q1022 TEMPO SCTOO6—



FAJS 060530Z 33013KT 9999 SCTO1O FEWO4OCB SCTO8O 19/17 Q1023 TEMPO SCTOO6=

1.7.3.2 SATELLITE IMAGE

The 0500 UTC infrared image figure 2 shows convective cloud over Gauteng and to northern KwaZulu-Natal.

1.7.3.3 FORECAST

The nearest terminal area forecast was for Johannesburg International Airport and is provided below:

FAJS 060000Z 060312 34010KT 9999 FEW030CB SCT080 PROB30 0306 4000 HZ SCTOO8 BECMG 0608 27010KT SCT020 T14/03Z T28/12Z=

The significant weather chart, valid at 0600 UTC, nearest to the time of the accident, gave isolated thunderstorms 9000 feet MSL (figure 4)

1.8 Aids to navigation.

1.8.1 Not applicable

1.9 Communications.

1.9.1 The aircraft was in communication with Rand Tower during the flight on 118.7 MHz and the recorded transmissions were transcribed as follows:

Transcript of Accident: Flight Charter 350, ZS-OJY. 06 DECEMBER 1999

FC – FLIGHT CHARTER SS - SLIPSTREAM
TWR- RAND TOWER FTL - FOXTROT TANGO LEAD (FIRE CREW)

00:00 (Start of communications with the pilot)

FC350 AND RAND TOWER FLIGHT CHARTER 350 IS READY ATC

TWR FLIGHT CHARTER 350 ATC ON REQUEST

00:57

TWR FLIGHT CHARTER 350 ATC

FC350 GO AHEAD SIR

TWR FLIGHT CHARTER 350 IS CLEARED AFTER DEPARTURE RUNWAY 29 MAINTAIN RUNWAY HEADING CLIMB TO AND MAINTAIN 8000 FEET PASSING 6500 FEET CONTACT RADAR 123 DECIMAL 7 FURTHER CLIMB AND ROUTING UNDER RADAR CONTROL SQUAWCK 5013

FC350 THAT AFTER DEPARTURE RUNWAY 29 TO MAINTAIN RUNWAY HEADING TO 8000 FEET CONTACT RADAR ON 123 DECIMAL 7 THROUGH SIX AND A HALF SQUAWCKING 5013 AND FLIGHT CHARTER 350 IS READY

TWR FLIGHT CHARTER 350 STANDBY

01:32

ZS-KGB AND KILO GOLF BRAVO'S READY

TWR KILO GOLF BRAVO SURFACE WIND 320 DEGREES 10 KNOTS CLEARED TAKE OFF RUNWAY 29 LEFT TURN REPORT ZONE OUT

ZS-KGB CLEARED TAKE OFF WILL REPORT ZONE OUT KILO GOLF BRAVO

01:49

TWR FLIGHT CHARTER 350 LINE UP AND WAIT RUNWAY 29 IN TURN

FC350 THANKS CLEARED TO LINE UP AND WAIT BEHIND THE 152 FLIGHT CHARTER 350

03:00

TWR LIMA GOLF GOLF CROSS RUNWAY 35

ZS-LGG CONFIRM LIMA GOLF GOLF

TWR AFFIRM LIMA GOLF GOLF CROSS RUNWAY 35

ZS-LGG LIMA GOLF GOLF CROSS RUNWAY 35

04:01

SS480 RAND TOWER SLIPSTREAM 480 READY FOR TAXI

TWR SLIPSTREAM 480 TAXI HOLDING POINT RUNWAY 29

SS480 TAXI HOLDING POINT RUNWAY 29 SLIPSTREAM 480

04:11

TWR FLIGHT CHARTER 350 THE PRECEEDING 152 ROUTING OUT VFR KEEP THE TRAFFIC IN SIGHT CLEARED FOR TAKE OFF WHEN READY SURFACE WIND 310 DEGREES 13 KNOTS REPORT PASSING 6500 FEET

FC350 CLEARED FOR DEPARTURE RUNWAY 29 WITH THE TRAFFIC DEPARTING TRAFFIC INSIGHT FLIGHT CHARTER 350 CALLING YOU SIX

AND A HALF THOUSAND FEET NEXT

05:33

FC350 RAND 350 REQUESTING AN IMMEDIATE BACK ONTO THE ACTIVE RUNWAY OR (29) PLEASE

TWR LAST CALL SAY AGAIN

FC350 FLIGHT CHARTER 350 WEVE GOT AN ENGINE FAILURE ON THE RIGHT AND WE ARE REQUESTING A LEFTHAND BACK ONTO 29

TWR FLIGHT CHARTER 350 REPORT SHORT FINAL APPROACH RUNWAY 3 CORRECTION RUNWAY 29 THE SURFACE WIND 310 DEGREES 10 KNOTS

TWR FLIGHT CHARTER 350 DO YOU COPY

FC350 WE GOING DOWN SIR WE GOING DOWN

TWR YOUR POSITION SIR

TWR FLIGHT CHARTER 350 SAY YOUR POSITION

06:06

FTL RAND TOWER FOXTROT TANGO LEAD.

1.9.2 It is noted that during initial communications with the pilot he sounded calm, but when he called to request to return to the field he was markedly stressed.

1.10 Aerodrome information.

1.10.1 The following aerodrome information was obtained:

Aerodrome Location	Rand Airport (FAGM)	
Aerodrome Co-ordinates	S26°14' E028°09'	
Aerodrome Elevation	5474 feet	
Runway Designations	11/29	
Runway Dimensions	1660 m	
Runway Used	29	
Runway Surface	Paved	
Approach Facilities	Not applicable	

1.11 Flight recorders.

1.11.1 Flight recorders are not a requirement for this category of aircraft.

1.12 Wreckage and impact information

1.12.1 A wreckage distribution diagram can be found at Attachment A to this report. At the initial impact point, the aircraft collided with some rocks on a magnetic heading of 290°. The initial contact was with the right-hand horizontal stabilizer, indicating a nose high, right-hand wing low attitude. Evidence from the crash site indicates that on the second impact the right-hand propeller separated from the engine, and came to rest 25 m to the right-hand side of the line of impact. The main wreckage was found a further 45 m on, where it impacted against the far bank of a water stream and turned through about 160° before it came to rest. The left-hand propeller was found a further 30m forward from the position of the main wreckage.

1.12.2 The wreckage was almost totally destroyed by the post-impact fire. The nose dome of the aircraft was found in a tree on the bank of the stream. A significant amount of the baggage fell into the water of the stream and was thus partly protected from fire damage. Several smaller fuselage fragments were also recovered from the stream.

1.12.3 The cockpit and cabin area of the aircraft was totally destroyed by the post-impact fire. The instrument panel was located but all the instruments were damaged to such an extent that no information could be derived from them.

1.12.4 The control systems were checked as far as possible, and no pre-impact defects were noted. It was noted that the flaps were retracted and the landing gear was up and locked.

1.12.5 A significant amount of baggage was recovered from the left-hand wing locker area. The turbulators of the vortex generator kit were observed on the left-hand wing fragments.

1.12.6 Both the engines suffered impact damage and fire damage. The engines and some of the fuselage fragments were recovered to an aircraft maintenance organisation on the afternoon of the accident.

1.13 Medical and pathological information.

1.13.1 Identification

Autopsies were performed on all the occupants of the aircraft. All of the bodies were burnt beyond recognition. Family, friends or colleagues positively identified eight bodies. This was achieved primarily by means of identification of jewellery and watches worn by the deceased. One of these bodies was identified by means of an implant on the left upper arm.

Two bodies could not be identified with certainty by these methods. These two bodies were later identified with certainty by means of DNA analysis.

1.13.2 General

All the bodies were weighed. It must be remembered, however, that due to the severe burning of the bodies, these weights cannot be used as indication of the real weights of the persons at the time of the accident. Due to the burning, there is an immense loss of water. Presently, no tables exist whereby an accurate mass of the body before the burning, can be deducted from the mass of the charred body.

1.13.3 Pilot

The cause of pilot’s death was noted as “fracture of the base of the skull compounded by acute severe burns”. No soot was present in the airways. Death most probably occurred at the moment of impact.

No evidence of pre-existing disease could be detected. On the routine toxicology screen no toxic substances could be detected and the alcohol concentration was 0,00 grams per 100 ml.

1.13.4 Passengers

The cause of death of the passengers was noted as multiple injuries and extensive burns. Soot was present in the major airways, indicating that they had inhaled the products of the fire immediately after the crash. The high levels of carbon monoxide detected in the blood have confirmed this.

In one of the passengers evidence of coronary artery disease was found, with an 80% occlusion of the left anterior descending artery. No evidence of pre-existing disease was found in any of the other passengers.

1.14 Fire

1.14.1 During the initial impact on the rocky side of the hill the fuel tanks were ruptured and large amounts of Avgas were released. The ignition source was considered to be from electrical arcing and/or contact with high temperature engine components.

1.15 Survival aspects

1.15.1 The impact forces associated with this type of accident would have allowed the accident to be a survivable accident. However, the post-impact fire rendered the accident non-survivable.

1.15.2 During the removal of the bodies indications were present that all the occupants had used their safety harnesses. The head injuries found on the pilot were indicative of not using the shoulder strap of the safety harness.

1.16 Tests and research.

Engines

1.16.1 The engines were recovered to an approved aircraft maintenance organisation for dismantling inspection. Due to the severe fire damage it was considered not viable to perform blow-by tests on the engines.

Left-hand Engine:

1.16.1.1 No significant damage was observed to the basic sub-assembly of the engine. There was some impact damage on the number 2 cylinder, but a fair amount of the rest of the damage was due to the post-impact fire. Most of the accessories fitted to the engine suffered extensive fire damage.

1.16.1.2 The cylinders were removed from the engine crankcase and no evidence of piston seizure or other abnormalities were observed in the cylinders.

1.16.1.3 Petrol checks were performed on all the cylinders except number 2 cylinder to check the sealing of the valves and they were found to be within limits. No abnormalities were observed with the valves and valve operating mechanisms.

1.16.1.4 The oil sump was removed from the crankcase. The bearings were inspected and no abnormalities were observed.

1.16.1.5 The connecting rods, crankshaft, big-end and small-end bearings were inspected. No abnormalities were observed on these components.

1.16.1.6 The spark plugs of the engine were removed. Only one spark plug fitted to number 6-bottom cylinder was damaged. Some spark plugs had oil on them, but the combustion deposits on the ones that were not contaminated were indicative of a normal running engine. All the spark plugs were tested and found to be operational.

1.16.1.7 It was impossible to check the magneto timing by means of a magneto timing light system due to the damaged state of the magneto. The magneto was removed from the engine, dismantled and inspected for serviceability. The magneto was extensively damaged and it was impossible to test as it was. The right-hand engine distributor gear, block and condensers were used and then the magneto tested normal under operational conditions. The harness was damaged beyond possible testing.

1.16.1.8 The fuel control unit and mechanical fuel pump were extensively damaged and impossible to test.

1.16.1.9 All the fuel nozzles except the nozzle fitted to number one cylinder were flow checked on a test bench (input pressure 12 PSI.) and the results were within the manufacturer's limits.

1.16.1.10 The differential pressure controller in the boost system and the density controller of the turbocharger system were damaged to the point where they could not be tested. No pre-impact damage was evident.

1.16.1.11 An inspection of the turbocharger revealed that the unit was seriously damaged during the impact. Both the turbine side and the compressor side of the turbocharger had evidence of rub-marks suggesting rotation of the turbocharger rotor. It is the conclusion of the qualified turbocharger technician from an approved aircraft maintenance organisation that the turbocharger was operational and running during the impact.

Right-hand Engine:

1.16.1.12 No significant damage was observed to the basic sub-assembly of the engine. There was some impact damage on number 1 and 2 cylinders, but a fair amount of the rest of the damage was due to the post-impact fire. Most of the accessories fitted to the engine suffered extensive fire damage.

1.16.1.13 The cylinders were removed from the engine crankcase and no evidence of piston seizure or other abnormalities were observed in the cylinders.

1.16.1.14 Petrol checks were performed on all the cylinders except number 1 cylinder to check the sealing of the valves and they were found to be within limits. No abnormalities were observed with the valves and valve operating mechanisms.

1.16.1.15 The partially melted oil sump was removed from the crankcase. The bearings were inspected and no abnormalities of the bearings were observed.

1.16.1.16 The connecting rods, crankshaft, big-end and small-end bearings were inspected. No abnormalities were observed on these components.

1.16.1.17 The spark plugs of the engine were removed. The electrode of the spark plug fitted to number 1 cylinder (bottom) was broken. Some spark plugs had oil on them, but the combustion deposits on the ones that were not contaminated were indicative of a normal running engine. All the spark plugs were tested and found to be operational.

1.16.1.18 It was impossible to check the magneto timing by means of a magneto timing light system due to the damage the engine sustained. The magneto was removed from the engine, dismantled and inspected for serviceability. No defects were evident and the magneto tested normal on the test bench with a test harness. The engine’s ignition harness was damaged beyond possible testing.

1.16.1.19 The fuel control unit and mechanical fuel pump were extensively damaged and was impossible to test.

1.16.1.20 Four of the fuel nozzles fitted to the engine were flow checked on a test bench (input pressure 12 PSI.) and the results were within the manufacturer’s limits. The fuel nozzle fitted to the number 6 cylinder had a small foreign object in it and was not flow checked. The number 2 cylinder was severely damaged during the impact and it was impossible to test the fuel nozzle.

1.16.1.21 The differential pressure controller in the boost system and the density controller of the turbocharger system were damaged to the point where they could not be tested.

1.16.1.22 A qualified turbocharger technician from an approved maintenance organisation inspected the turbocharger and he concluded that all moving parts and condition of materials were found to be normal and no sign of disruptive cause of failure could be found. The backplate assembly was cracked and broken most probably due to impact. It was the technician’s opinion that the turbocharger was not running at the time of impact. His statement is made in consideration of the fact that there were no visual rubbing marks present, which should have occurred if the turbocharger was operational.

1.16.1.23 During the dismantling of the exhaust system it was found that the exhaust pipe segment from the right-hand bank of the engine where it was fitted to the turbocharger manifold had broken loose (refer to photo on right). There was no impact deformation of the exhaust pipe segment and the combustion deposits around the failure suggested that the failure existed before the accident. There was a fragment missing from the flange fitted to the end of the exhaust pipe segment (refer to the lower photo on the right). The failed pipe was taken to a metallurgist for further failure analysis.

Turbocharger system operation

1.16.2 At this stage a description of the operation of the turbocharger system would be advantageous to be able to give the reader a better understanding of the consequences of the exhaust pipe segment failure:

1.16.2.1 A schematic illustration of the turbocharger system is as follows:

1.16.2.2 The turbocharger is designed to increase power output and efficiency of the engine by supplying compressed air to the engine intake manifold. This allows the engines to operate at peak power at a much higher altitude than normally aspirated engines. The power to drive the turbocharger is extracted from energy in the exhaust gases. The exhaust gases are ducted through the turbine and then directed overboard at the bottom of the nacelles in the area of the cowl flaps.

1.16.2.3 The exhaust pipe segment failed where the segment was clamped to the exhaust bypass valve assembly as indicated. This failure caused a loss of mass flow of exhaust gasses and an associated drop of pressure in the exhaust manifold to the turbine side of the turbocharger. The decrease in mass flow and pressure of the exhaust gasses on the turbine side of the turbocharger will cause a reduction in speed of the rotor assembly, which in turn will cause a reduction in the effect of the compressor side of the turbocharger. This will cause the mass flow of inlet air and the inlet manifold pressure to decrease with an associated loss of engine power.

Simulation of defect on another engine

1.16.3 The exhaust pipe segment defect was simulated in a similar type of aircraft with the same type of engine. At first by loosening the clamp connecting the exhaust manifold pipe segment to the turbocharger manifold with no effect to the maximum power output of the engine (maximum manifold pressure 42 inches). By loosening the clamp completely the manifold pressure only increased to 28 inches and the fuel flow was limited to 18 gall/hour.

Engine Manufacturer’s opinion

1.16.4 The engine manufacturer was contacted and asked for their opinion on the possible reaction of the engine at the time of the exhaust pipe segment failure. The air safety investigator’s opinion was that he would expect the engine to go into a normally aspirated mode or a very close to that condition. He state that it is possible that a rich condition would exist, but at higher throttle settings he would not expect the engine to quit due to an over-rich condition, but expect a 40% to 50% reduction in power. He referred to a documented case of a similar engine, which suffered an exhaust system failure at full power setting and stated that the manifold pressure reduced to 28,8 inches of mercury, with the power of the engine down to 223 horsepower. The test engine’s rated power output was 310 horsepower at 2575 RPM at 38.6 inches manifold pressure.

Similar crack on another aircraft

1.16.5 During a visit to the facilities of the aircraft maintenance organization the investigator-in-charge found a similar crack on a similar aircraft undergoing maintenance work. This crack has progressed half way around the exhaust manifold pipe segment at the flared area. The exhaust pipe segment was removed and taken to the metallurgist as a reference pipe to analyze during his investigation of the broken flange found on the right-hand engine of the accident aircraft.

Propellers

1.16.6 A qualified propeller maintenance engineer from an approved aircraft maintenance organisation inspected both the propellers and it was his opinion that the right-hand propeller was in a feathered pitch position at the time of the impact. His analysis is based on the fact that only two blades were damaged, the third was not scratched. The spinner in the area of the damaged blades was also damaged, yet no damage occurred in the area of the unaffected blade. Also, there were no radial score marks on the blades as to indicate the rotational motion of the propeller. Further the pitch change rod was damaged in such a way that could only be achieved if the propeller was in the feathered pitch position.

1.16.7 It was the opinion of the propeller maintenance engineer that the left-hand propeller was in motion (rotating) at the time of impact. His analysis is based on the fact that all three blades were damaged extensively. Radial score marks on the blades also indicate rotary motion. The pitch change rod was broken just below the pitch change fork, which would only be possible if the propeller was in a “flying” pitch (position). The spinner also has damage all the way around.

Metallurgical analysis of exhaust pipe segment failure

1.16.8 Extracts of a metallurgical evaluation report relating to the fractured exhaust pipe segment from the right-hand engine of the accident aircraft and a similar cracked exhaust pipe segment from another aircraft are attached to this report as Appendix C. The metallurgical analysis found that the material of the pipe was the normal type of metal used for exhaust applications. The crack propagation in both pipes could be attributed to fatigue and the metal cracked in such a way that small pieces broke away. This would cause an increased exhaust gas leak.

The different oxidation- and/or exhaust gas debri layers on the fracture surfaces indicated that there were some areas where the cracks had existed for some time and some areas which had indications of fresh cracks. It is suggested that due to thermal and possibly also vibration stresses to which the entire manifold system is subjected during engine operation, a fatigue crack was formed in the flange radius area adjacent to the clamp fixation with the waste gate of the exhaust system. The crack surfaces were exposed to exhaust gas oxidation and possible erosion. These deposits damaged the fracture surfaces to such an extent that no fatigue evidence was visible, except for the vague fatigue striations adjacent to the fractured pipe flange mating surface ring. The flange mating surface ring section was eventually sheared over the entire cross-section and was subjected to higher temperatures, hence the discoloration. The sudden fracture of the flange-mating surface resulted in the pipe bending sideways and pulling the crack surfaces well apart. This action would have immediately intensified any exhaust gas blow out or leakage from that area.

The engine manufacturer’s response

1.16.9 Communications between the investigation team and the engine manufacturer suggested that the manufacturer has previously seen such failures and believe they occur as a result of improper installation and maintenance of the components, together with a lack of proper pre-flight and periodic inspections.

1.16.10 The manufacturer referred to Service Instruction Number 1410 issued by AVCO Lycoming on 19 June 1981 regarding the improvement of exhaust manifolds on the TIO-540-A, -F, -J, -R and –C models. A 3° bend was incorporated in the new exhaust pipes and an increased length of slip joint. A lengthy discussion about the assembly of the exhaust manifold is included in the service instruction. It warns that uneven tightening of exhaust parts may cause damage resulting in loss of exhaust gas pressure and all slip joints should be lubricated with the prescribed anti-seize lubricant. If any part of one side of the exhaust system is removed or replaced for any reason, all the attachments on that side should be loosened before the installation of the new or removed component. During the assembly each attaching part should be tightened equally and uniformly.

1.16.11 Several other Service Instructions (Number: 1391 of 5 October 1979, 1320 of 7 March 1975, 1204B of 25 April 1986 and 1190 of 7 June 1968) refer to similar points of the exhaust manifold maintenance.

1.16.12 In the Textron Lycoming Operator's Manual for the engines it states that during a daily pre-flight inspection the turbochargers should be inspected for several points, including air or exhaust gas leakage. This is very difficult to accomplish during a daily pre-flight inspection if the engine cowls are in place. During the 50 and 100 hour inspections, pertinent inspection items are called for on the exhaust and turbocharger systems, and a CAUTION note about the operation of the turbochargers is included.

1.17 Organisational and management information

1.17.1 Flightline Charter Services

Flightline Charter Services was issued a Class II Air Services Licence (N476D) valid for N1, N2 air services (cargo, mail, passengers), on 18 March 1996. The company was subsequently issued with an AOC (N476D/OC1) on 19 April 1996.

Flightline had operated as an air charter company since that time, in which company business is reported to have doubled each year. In particular, 1999 appears to have been a very active year for the company.

At the time of the accident Flightline Charter Services Operating Certificate had expired. Section 1.17.2.5 of this report detail several anomalies in the processes involved in the issue and maintenance of this carrier's AOC.

1.17.1.1 Management structure

In terms of management structure, Flightline is a small operation. The company founder and Chief Executive Officer holds the position of Responsible Person: Aircraft, and is also a line pilot. Other management positions include the General Manager (non-flying), who also acts as Responsible Person: Flight Operations, the Chief Pilot, and the Aviation Safety Officer/Senior Pilot (who perished in the accident). The Chief Pilot had held his position since 1

November 1999. The Aviation Safety Officer/Senior Pilot had held his position since March 1999.

1.17.1.2 Flight crew

At the time of the accident the company employed a total of five operational pilots, including the three management pilots detailed above. The total flying experience of these pilots was as follows:

CEO/Responsible Person: Aircraft:	1,488.9 hrs
Chief Pilot:	1,844.6 hrs
Aviation Safety Officer/Senior Pilot (killed in accident):	1,444.9 hrs
Pilot A:	757.1 hrs
Pilot B:	1100 hrs

1.17.1.3 Safety management

Interviews conducted with Flightline management and staff since the accident indicate that there was no formal process of regular Flight Operations meetings or briefings in place at the carrier. Nor were there any formal safety management, safety promotion or safety occurrence reporting programs in existence at the company. While the Chief Pilot and the Aviation Safety Officer had discussed the need for such activities, it appears that their resources were stretched and up until the time of the accident no such activities or programs had been implemented.

1.17.1.4 Check and training

Flightline did not employ a Training Captain at the time of the accident. It also appears that there was no formal proficiency checking, route training or recurrent training program in place at the time of the accident. When mandatory checking or training requirements arose they were conducted by an external organisation.

1.17.1.5 Regulatory compliance

In relation to issues of regulatory compliance, inspection of Flightline company records indicated that considerable deficiencies existed with regard to requirements laid down within the approved company operations manual. These deficiencies can be categorised into the following areas:

a. Personnel record keeping;

b. Aircraft documentation;

c. Operational documentation (eg., load and trim sheets, flight folio);

d. Compliance with flight and duty time limitations requirements;

e. Flight training (eg., operator and technical proficiency checks, recurrent route training, dangerous goods training).

1.17.1.6 Commercial versus Safety

The management of any aviation transport organisation must continually arbitrate between the often conflicting goals of safety and profitability. Achieving an appropriate balance between these goals is difficult, but necessary. From discussions with Flightline company management it is clear that they possess a strong business planning and commercial orientation. It can also be observed that this may take priority over their experience, skills and interest in certain aspects of flight operations management and it may be that this is reflected in some of the deficiencies noted above.

Flightline management devoted significant resources to matters of business planning, customer service and commercial imperatives. While this is desirable for the survival of any commercial entity, it is believed that the organisation's balance between the goals of safety and profitability may have been inappropriate, and that the commercial success experienced by the organisation may at times have been achieved at the expense of insufficient attention paid to matters of operational supervision and safety.

1.17.1.7 History of previous violations

Evidence suggests that the deviations from standard operating procedures, noted for the accident flight (flying with an overloaded aircraft; not weighing passengers and baggage nor completing required mass and balance documentation) were not isolated incidents at Flightline. Statements provided to the investigation team from friends and relatives of the deceased pilot suggest that he had previously expressed concerns to them in relation to such matters. Scrutiny of information of previous flights conducted for the same client suggests that most or all of these previous flights were also operated with an overloaded aircraft. Research into fuel uplift figures on previous flights also indicates that Flightline flight crew had on occasions operated aircraft below legal minimum fuel requirements. This evidence has been corroborated by independent sources with knowledge of operational standards at the company.

1.17.1.8 Organisational culture

Primary responsibility for the safe operation of any aircraft flight rests with the pilot-in-command. Pilots are trained to make judgements and decisions in relation to principles of good airmanship, and the final decision as to whether a flight departs or continues under safe conditions is that of the pilot-in-command. As discussed below, the decision of the pilot-in-command to operate the accident flight under the conditions described above was clearly an 'unsafe act'. However, unsafe acts are rarely committed in isolation, and are usually related to the professional, organisational and in some cases the national culture in which the individual operates.

One must keep in mind the responsibilities placed on the operator under Part 135 of the Civil Aviation Regulations of 1997. In this regard indications are that the organisational culture existing at Flightline Charter Services at the time of the accident might have been one, which encouraged, or at best did not discourage pilots from non-compliance with legislative prescriptions.

1.17.1.9 Operational documentation

As indicated above, several aspects of operational practice at this operator were found to be inconsistent with requirements laid down within the approved company operations manual. During interviews conducted with Flightline staff if was apparent that their familiarity with the requirements laid down in some very pertinent sections of this manual was generally poor.

It appears that this is a widespread trend at this level of the aviation industry. In many cases, operations manuals are compiled by aviation consultants. These consultants are very familiar with the CAA requirements with respect to the production of these manuals, but may be less familiar with the actual requirements of individual operators. They produce a 'generic' manual, which fulfils regulatory requirements, but may not be suitable for all aspects of their client's operations. In addition, as the manual has been produced by an external consultant and may not have been customised to fit their organisation's requirements, operational staff at the customer is often unfamiliar with the contents and/or meaning of some sections of the manual.

1.17.2 Civil Aviation Authority

Regulation of civil aviation in South Africa is conducted by the South African Civil Aviation Authority (CAA), which was established on 1 October 1998, following the enactment of the South African Civil Aviation Authority Act in September 1998. The Act provides for the establishment of a stand-alone authority charged with the promotion, regulation and enforcement of civil aviation safety and security in South Africa.

The creation of the CAA was a product of the Government's new priorities of policy development, economic restructuring, addressing social inequalities and the implementation of a "user-pays" system. Additionally, the previous regulator (the National Department of Transport) had been struggling to fulfil its functions and was operating with decreasing funds, increasing workloads and an inability to attract and retain skilled staff.

1.17.2.1 Culture change

In the 14 months from the establishment of the CAA until the time of the accident, the transition from the old to the new regulator involved issues of considerable complexity. The CAA is a new organisation, operating under new legislation, with new operating procedures and a new way of doing business; in essence, a new organisational culture. This new business orientation reflects a strong emphasis on developing and maintaining high levels of customer service, and is accompanied by a schedule of increased customer charges.

From an organisational culture perspective, it is clear that the new CAA is attempting to promote different staff values and practices to those long established within its predecessor. This has also created some difficulty in the transition from the old to new organisation as some members of staff struggle to adapt to, and in some cases resist, the transition to a new organisational culture. In addition to the above and at the same time, the regulatory framework of Civil Aviation in South Africa changed partially from the Air Navigation Regulations of 1976 to the Civil Aviation Regulations of 1997. The complexity of the situation was compounded by the fact that this change is still ongoing.

1.17.2.2 Resource issues

The new Civil Aviation Regulations relating to the Air Operators came into effect on 1 January 1999 after it was published on 1 January 1998. The time between October 1998 and the end of December 1998 were set to approve the Operations Manuals of the Air Operators. The industry was initially slow to submit their operations manuals, but the flight operations department was flooded with operations manuals towards the end of 1998. The flight operations department was thus unable to carry out inspections at operators until such time as the operator's operations manual was approved and the inspection could be carried out in accordance with the manual. Due to staff shortages in the flight operations department, not all of these manuals were approved and a large proportion were not even submitted by the end of December 1998. A moratorium was given to the operators to submit their operation manuals till end of March 1999 with the understanding that their current AOC would be extended on receipt of their manual of procedures and fee until an inspection could be carried out in respect to the new manual.

A further issue brought to the attention of the investigation team is that in order to adapt to and develop the new structure and practices of the CAA, flight operations inspections were also partially restricted for a period of approximately six months between 1 October 1998 and April 1999. Only the inspections as a matter of urgency were carried out. Operations manuals were developed for the different departments of the CAA to be able to have a legal basis from which inspections were carried out. The flight operations department's operations manual was one of these manuals that were developed during this time. Both the above aspects created a considerable backlog of inspections to be conducted, and impacted negatively on staff morale.

1.17.2.3 Surveillance anomalies

It is clear that the above factors contributed to the development of several anomalies in the performance of the regulatory surveillance role and functions of the CAA in the time leading up to the accident. In relation to the specific case of Flightline Charter Services these anomalies included issues of airworthiness and flight operations surveillance and in particular the fact that Flightline was not in possession of a current and valid AOC at the date of the accident.

In addition, it is clear that some practices, which were considered to be integral to the airworthiness and flight operations surveillance functions in the Chief Directorate:Civil Aviation Authority were discontinued in recent times.

Clarification of the exact nature of the anomalies referred to above and their possible contribution to the accident causation cycle are addressed below.

1.17.2.4 Airworthiness inspection

The CAA aircraft file was consulted to determine the chronology of events within the certification process for the accident aircraft. A summary of these events is as follows:

- An application for registration was received from the aircraft maintenance organisation dated 30 March 1999. It included:
  - The de-registration certificate of the aircraft from the register of the Democratic Republic of Congo, dated 17 March 1999
  - An application of registration in the name of Placo Aircraft Sales
  - An Import permit
  - A letter from the CAA Engineering Department to confirm the details of the aircraft
  - The Certificate of Airworthiness of the aircraft issued by the Democratic Republic of Congo.
- An application for a Certificate of Airworthiness dated 30 March 1999 was

also received and on this application form the Maximum Certificate mass was indicated as 3202 kg (7059,2 lbs.).

- An application for the issuing of a Special Flight Permit dated 31 March 1999 was received. The application indicated that the reason for the flight was a C of A test flight. The proposed flight crew was indicated as a Type Rated Test Pilot.

- The Special Flight Permit was issued on 1 April 1999. Expiry date was 5 April 1999.

- The required mandatory periodic inspection of the aircraft was carried out and certified on 14 April 1999. Copies of the Certificate of Safety for Flight and the relevant pages of the new logbooks were inserted in the CAA aircraft file.

- Two airworthiness inspectors carried out an inspection of the aircraft on 14 April 1999 as a requirement to issue a Certificate of Airworthiness. The inspection checklist indicated that AD98-09-25 was still outstanding due to a shortage of spares. There are no indications of responses to items relating to the cabin material fire requirements or safety equipment in the cabin. No modifications are noted under the relevant section of the documentation. Where the checklist requires that modifications are recorded as required and the correct release documentation exists, it is marked as “complied with”. There was an entry in an old logbook of the aircraft that the vortex generator kit was fitted in Kinshasa, Zaire on 13 May 1994. The checklist is certified by the chief inspector of the aircraft maintenance organization.

- The mass and centre of gravity determination and the equipment checklist were certified on 9 April 1999 by the chief inspector of the aircraft maintenance organization. The mass and center of gravity of the aircraft was determined on a typical form for the aircraft, but an error was made when the empty mass of the aircraft (4594.385 lbs.) was carried over from the calculation table to the table at the bottom of the page, where empty mass was indicated as 4394.385 lbs. No evidence was found that the modifications involving the vortex generator kit or the nacelle fuel system already fitted to the aircraft were included in the equipment checklist.

- The Flight Performance test flight was carried out on 13 April 1999 by the Responsible Person: Aircraft (also the owner and CEO) of the operator. At the date of the test flight the special flight permit had expired (5 April 1999), and while the pilot that flew the aircraft was rated on type, no evidence was found on the pilot’s CAA file that he was in possession of a test pilot rating. The single engine climb performance of the aircraft as recorded on the test form was much higher than the climb performance indicated in the Pilot’s Operating Handbook (refer to 1.6.22 of this report). No evidence was found that the airworthiness inspector either noted or questioned this flight test performance anomaly.

- The airworthiness inspector approved the Flight Manual of the aircraft on 14 April 1999. A Special Flight Permit was issued on the same day (date of expiry: 13 May 1999) in order that further test flights may be carried out on the aircraft if required while a Certificate of Airworthiness was prepared.

- On 16 April 1999 the airworthiness inspector approved the request to issue a Certificate of Airworthiness and the regional inspector certified the request on the same date. The Certificate of Airworthiness for the aircraft was issued on 16 April 1999.

- The change of ownership was carried out and the aircraft was registered in the name of the operator. A Certificate of Registration was issued on 5 May 1999.

1.17.2.5 Flight Operations inspection

The Chief Directorate: Civil Aviation Authority (CD: CAA) of the Department of Transport, carried out the Flight Operations inspection functions in South Africa before October 1998. This function was transferred to the Flight Safety Operations Department of the Civil Aviation Authority (CAA) when the CAA was established in October 1998.

Following the accident a CAA officer (co-opted onto the accident investigation team) completed a report reviewing regulation and surveillance activities concerning the operator. The following are pertinent observations from that report:

CD: CAA oversight:

- An application for the renewal of the operator's Operating Certificate was made on 24 February 1997 (initial Operating Certificate due to lapse on 10 April 1997). An inspection report dated 11 March 1997 was the first inspection report on the operator's CAA file. No adverse comments were recorded and a recommendation was made for renewal. The operator was issued an Operating Certificate on 4 April 1997, valid to 7 May 1998. The Operating Certificate was mailed to the operator on 8 May 1997. Letters on file referred to an application dated 1 March 1997. However no evidence of that application could be found.

- On 6 May 1998 an inspector completed an inspection report although no application for renewal could be found on the CAA operator file.

- Comments on the CD:CAA inspection report dated 7 May 1998 were in the line of:

  - Administration

    1. Air Law - One amendment behind;
    2. Loadsheet (the report does not indicate what problem existed with the loadsheets);
    3. Change Ops. Manual (no indication is given as to what changes are required).

  - Recommendations

    - The inspector recommended renewal of Operating Certificate referring to an office note for other recommendations;
    - The Head of Section indicates agreement with the office note and requests for an inspection to be carried out in 30 days;

- On a CD:CAA office note (dated 7 May 1998) the following observations were recorded:

- Operations Manual to be updated in respect of changes to aircraft list and the section dealing with the requirement for loadsheets for aircraft under 1600 kg.
- Aviation Legislation amended to No.18. This is one amendment behind.
- Loadsheets not being correctly completed.

  - Recommendations (by Inspector)
    - Give operator 21 days to correct deficiencies;
    - Spot-check loadsheets for compliance when conducting inspections in the area;
    - Recommended renewal of Operating Certificate Comments from Head of Section on recommendations;
    - "Re-inspection to be carried out in 30 days".

- It is noted that the CAA operator's file includes no record confirming that re-inspection was conducted as requested by the CD:CAA Head of Section. This re-inspection should have occurred prior to 7 June 1998.

CAA oversight:

- A fax message to the operator dated 19 November 1998 requested information for all aircraft operated by the operator (to be submitted by 23 November 1998). It was further requested that a copy of their Operating Certificate be forwarded. A statement with regards to whether there were any operations conducted since 4 May 1998 was also requested (Operations Certificate valid to 7 May 1998 according to CAA file).
- A second fax message to the operator is dated 26 March 1999 (four months later). This communication included a copy of the fax of 19 November 1998, and indicated that no response was received; it further indicated that no application for renewal of the company's Operating Certificate had been received, and that the previous Operating Certificate had expired on 7 May 1998.
- A response from the operator to the CAA communication dated 26 March 1999 was received. In this undated document information as requested on 19 November 1998 was furnished together with a copy of their Operating Certificate issued on 8 May 1998 by the CD:CAA and valid to 7 May1999.

Note:

- No record exists regarding re-inspection within 30 days as requested after inspection dated 6 May 1998 by the CD:CAA head of section;
- No application for the renewal of Operating Certificate was held on file brought over from the CD:CAA;
- No inspection record is held on file leading to a recommendation for renewal of the Operating Certificate.

- A subsequent application to the CAA for renewal of the Operating Certificate was dated 13 April 1999. Attached was a copy of the Operating

Certificate issued on 8 May 1998 with expiry date of 7 May 1999.

Note:

- The rule during this time was that if an operator applied for a renewal of their AOC 30 days or more before the expiry date of the current AOC, no inspection would be required for a renewal, but in this case the renewal application was made less than 30 days before the expiry date of the AOC, hence an inspection was required;

- On 21 May 1999 the CAA carried out an inspection of the operator. The inspector as on the previous occasions, accompanied by another inspector, carried out the inspection and some administrative non-compliances were found.

Note:

- No report of this inspection was filed because the inspector having found some non-compliances had given the operator some time to rectify the non-compliances;

- A follow-up inspection was subsequently carried out on 2July 1999 and the inspector noted on the original inspection report of 21 May 1999 (which was not submitted after the inspection on 21 May 1999) that the non-compliances were now rectified and he signed on 2 July 1999. Outstanding documents were detailed in a memo from the inspector to the Head of the Section dated 2 July 1999 (apparently before he went for the inspection). These were:

  - Management Plan
  - Two aircraft without insurance due to being on the ground for maintenance
  - Four aircraft with old Certificate of Airworthiness.
  - Radio Licenses for five aircraft need updating
  - Certificate of Registration for one aircraft outstanding
  - Flight Folio to reflect:
    - Fuel and oil uplifts
    - One journey per line entry
    - That snags have been cleared by an authorized Person
    - Completed flight folios should be filed

Note:

- There was a time lapse from 2 July 1999 to 20 September 1999 before any further action was noted on the inspection report;

- On 20 September 1999, the CAA acting Head of Section (OPS) requested response from the Airworthiness Section regarding outstanding items. He instructs not to issue Operating Certificate.

- On 21 September 1999, the CAA Project Manager: Personnel Oversight instructs "temporary" Operating Certificate to be issued for 30/60 days.

Note:

- An internal arrangement existed at the time within the flight operations department to issue “temporary” Operating Certificates in order to give the large number of operators who had not complied with the new regulatory requirements, time to comply. In this case the non-compliances was of an administrative nature;

- A Temporary Operating Certificate was subsequently issued on 29 September 1999 by the CAA and was valid until 29 November 1999.

Summary of the above process:

- The move from the Department of Transport building to the new premises of the South African Civil Aviation Authority took place during September and October 1998. It was possible that during this time some of the documents could have been miss-filed or lost in the registry.
- The new Civil Aviation Regulations for Part 135 operations only came into effect by 1 January 1999. According to the Project Manager: Personnel the Part 135 operators were not required to have operating manuals before 1 January 1999. The dealings with these operators were to bring them in line for the implementation of the regulations on 1 January 1999.
- An inspection was carried out on 21 May 1999 after Operating Certificate had expired.
- The inspector concerned enters recommendations on 2 July 1999 (more than a month after inspection).
- On 20 September 1999 (almost three months later) the Head of Section (Acting) remarks that an Operating Certificate should not be issued.
- On 21 September 1999, the relevant Project Manager authorises issuing of “temporary” Operating Certificate for a period of 30 to 60 days as well as follow-up and feedback. No provisions for such a “temporary” Operating Certificate were found in the Civil Aviation Regulations of 1997, but the Project Manager: Personnel Oversight acted on an internal arrangement agreed by the General Manager: Air Safety Operations pertaining to operating certificates.
- This certificate expired on 29 November 1999.

1.17.2.6 Confidential Hazard Reporting Scheme

A confidential hazard reporting scheme was in existence in South Africa until April/May 1999. This scheme was administered by the South African Aviation Safety Council, but was discontinued.

1.17.3 Air Services Licensing Council

Airline operators in South Africa are required to obtain an Air Services Licence from the Air Services Licensing Council. The Air Services Licensing Council was established by the Air Services Licensing Act of 1990 “for the licensing and control of domestic air services; and for matters connected therewith”.

The CAA provide technical support to the Air Services Licensing Council during the initial evaluation of an applicant’s application. The application for an air service license are circulated in the CAA to give the different sections opportunity to be able to evaluate the application with relation to adequacy of equipment and staff. The applicant’s application then serves on a hearing of the council where a CAA member then represents the CAA on the council. The function of the CAA member during the hearing is to provide the council with technical support.

1.17.4 Aircraft Maintenance Organisation

The Aircraft Maintenance Organisation (AMO) which provided maintenance oversight for Flightline Charter Services was Placo (Pty) Ltd. Placo performed the airworthiness inspections on the accident aircraft when it was imported into South Africa.

An inspection was carried out on 5 March 1999 at the aircraft maintenance organisation to be able to renew the Aircraft Maintenance Organisation's licence. The airworthiness inspector that inspected the aircraft also carried out the aircraft maintenance organisation renewal inspection. A checklist (named Inspection Checklist for Organisations Seeking CAR 145 Approval) was used during the inspection and at the bottom of the inspection checklist the following is indicated:

Airworthiness Manual of Procedures, January 1999 Draft

Under the section about the **Store** there are notes made to a point in the checklist and then no more comments or marks were made. The last question that was marked is: Does the store hold shelf life products? The answer provided was "yes", but the next question: How are standards maintained with respect to those products? was not answered and from there onwards none of the questions on that page. At the end of the inspection checklist it was recommended that the Aircraft Maintenance Organisation's Certificate of Approval be renewed. A note state that:

This recommendation for the approval of the renewal of this Certificate of Approval is conditional to re-structuring and phasing in into Manual of Procedures as per Civil Aviation Regulations of 1997.

The Certificate of Approval of the Aircraft Maintenance Organisation was issued on 28 February 1999.

No evidence was found on the CAA file of the Aircraft Maintenance Organisation that the conditions set in the recommendation were implemented.

As noted above, neither the vortex generator kit nor the Nacelle Fuel System, both previously fitted to the aeroplane, were included on the airworthiness inspection documentation or the approved equipment checklist.

1.18 Additional information.

Quotation for Oranjemund flights

1.18.1 The financial officer of the charter service client requested quotations from several operators for the intended weekly flights to Oranjemund. She received three quotations and accepted the lowest-priced offer, which was that of Flightline Charter Services, indicating that they would be able to fly seven to nine passengers and 10 kg of baggage per passenger to Oranjemund in a Piper Chieftain aircraft. The other operators quoted to fly nine passengers and 10 kg of baggage per passenger in a Beechcraft Kingair B200 and were not prepared to fly that amount of passengers in a smaller aircraft over the distance.

1.18.2 The original plan was to fly from Rand Airport to Upington and then on to Oranjemund. The stop at Upington would serve as a fuel stop. The first flight was flown this way, but the second flight was flown on a direct route from Rand Airport to Oranjemund. The third flight was also flown with a fuel stop at Upington, but from the return flight onwards all flights were conducted on direct routes between Rand Airport and Oranjemund. In the light of the above a typical flight profile for the direct flights from Rand Airport to Oranjemund was calculated as this was the usual way most of these flights were conducted.

1.18.3 The distances to the check points as indicated on the flight plan that was filed for the ill-fated flight were used and typical power settings were obtained from the CEO/Responsible Person: Aircraft of the operator. He provided the following typical settings:

Phase of flight	**RPM setting**	**Manifold Press.**	**Fuel flow**
Take-off	2575 RPM	38”	Full Rich
Climb (600-700 ft/min.)	2400 RPM	35”	48 gph
Cruise	2200 RPM	30”	34 gph

1.18.4 The submitted flight plan indicated a cruise speed of 170 knots and the Pilot’s Operating Handbook was used for the additional values needed (Assumed flight level of 100). The following distances and times were determined:

Descent according to Pilot’s Operating Handbook:

Location to	**Distance**	**Time @ 170 knots**
Rand	0	0
Top of climb (Rate of 600 ft/min from 5474 ft @ 101 knots)	12.63 nm	7.5 min
Klerksdorp (KD)	75.38 nm	26.5 min
Sishen (SS)	205 nm	72.5 min
Upington (UPV)	102 nm	36 min
Top of descent (130 knots and 500 ft/min from 10000 ft. to sea level)	205 nm	72.5 min
Oranjemund (FYOG)	50 nm	20 min
Total:	650 nm	235 min. / 3hrs. 55 min.

Descent according to normal operating practices:

Location to	**Distance**	**Time @ 170 knots**
Rand	0	0
Top of climb (Rate of 600 ft/min from 5474 ft @ 101 knots)	12.63 nm	7.5 min
Klerksdorp (KD)	75.38 nm	26.5 min
Sishen (SS)	205 nm	72.5 min
Upington (UPV)	102 nm	36 min
Top of descent (170 knots ground speed and 500 ft/min from 10000 ft. to sea level)	198 nm	70 min
Oranjemund (FYOG)	57 nm	20 min
Total:	650 nm	232.5 min./3hrs. 52.5 min.

The direct distance from Rand Airport to Oranjemund was measured and the direct distance was determined as 640 nm. The 10 nm difference in distance constituted only a difference of about 2 minutes flying time and will thus be neglected. A similar argument stands for the differences in time for the descent, so the values in the Pilot’s Operating Manual will be used.

1.18.5 If these times and settings are used to calculate the fuel needed to fly the flight the following was determined:

Phase of flight	Time	Fuel
Take-off & climb (48 gph)	7.5 min.	6 gall.
Cruise (34 gph)	207.5 min. / 3.46 hours	117.58 gall.
Descent (Operating Handbook)	20 min.	6.667 gall.
Total:	235 min. / 3.917 hours	130.25 gall.

1.18.6 The operator's flight operations manual was used and according to their fuel policy the following fuel load was determined:

	Condition	Fuel Quantity	Mass (6 lbs./gall)
Basic Fuel		130.25 gall	781.48 lbs.
Contingency fuel	5 % of basic fuel	6.51 gall	39.08 lbs.
Alternate fuel	5 min. cruise to reach alternate aerodrome (Alexandra Bay)	2.83 gall	17 lbs.
Final reserve fuel	30 min. cruise plus 5 %	17.85 gall	107.1 lbs.
Total:		157.44 gall	944.66 lbs.

Note: The operator's operations manual referred to 30 minutes final reserve fuel. The CATS-OPS 91.07.12 requirement is 45 minutes final reserve fuel for aircraft with reciprocating engines.

1.18.7 These values for the fuel load were used and the pilot's mass was taken as 85 kg as prescribed in the CATS-OPS 91.07.11. The mass of the passengers were used as in the operations manual of the operator (Males = 96 kg. and females 78 kg.). These values include baggage. The mass of the standard cooler box with cool-drinks of the operator is 22 lbs. If these masses were used to determine the mass of the aircraft as it should have been used when the operator quoted for these flights it would be as follows:

	Mass (lbs)
Basic aircraft	4594.385
Pilot at 85 kg. or	187.39
3 Male passengers at 96 kg or 211.64 lbs. each	634.92
6 Female passengers at 78 kg or 171.96 lbs. each	1031.76
Rear cool drinks	22
Fuel as calculated	944.66 lbs.
TOTAL	**7416.115 lbs.**

1.18.8 When the fuel load and the total mass of the aircraft were calculated in a similar method as above for a flight from Rand Airport to Upington, the total mass of the aircraft was calculated as 7200.93 lbs. The fuel load was calculated as 730.47 lbs. with Sishen as the alternate airport.

1.18.9 The operator quoted the computer company that they would be able to transport 9 passengers each with 10 kg. of baggage to Oranjemund in this aircraft. The maximum take-off mass of the aircraft is 7000 lbs. not considering density altitude compensation. If this is taken into consideration it suggests that the operator has quoted the company on an aircraft that would fly these flights in an over-loaded condition.

Previous flights to Oranjemund

1.18.10 A summary of the previous flights by the operator to Oranjemund was made and the following spreadsheet was created about these flights. The fuel uplifts were obtained from the different points where the two aircraft were refuelled and the pilots were identified as pilots 1 and 2 (pilot 1 being the alternate pilot that flew this route and pilot 2 being the pilot of the ill-fated flight on 6 December 1999):

Date	**Aircraft**	**From**	**To**	**Fuel uplift**	**Where**	**POB**	**Pilot**	**Time**
02/10/1999	ZS-JJB			552 L / 145.8 Gall	FAGM			
04/10/1999	ZS-JJB	FAGM	FAUP		FAGM	1 + 9	1	
04/10/1999	ZS-JJB	FAUP	FYOG	401 L / 106 Gall	FAUP	1 + 9	1	4
				No Upl	FAAB			
08/10/1999	ZS-JJB	FYOG	FAUP	525 L / 138.7 Gall	FAUP	1 + 9	1	
08/10/1999	ZS-JJB	FAUP	FAGM			1 + 9	1	4.3
17/10/1999	ZS-OJY			548 L / 144.8 Gall	FAGM			
18/10/1999	ZS-OJY	FAGM	FYOG			1 + 9	2	4.17
22/10/1999	ZS-OJY	FYOG	FYOG	764 L / 201.9 Gall	FAAB	1	2	
22/10/1999	ZS-OJY	FYOG	FAGM			1 + 9	2	3.92
23/10/1999	ZS-JJB			620 L / 163.8 Gall	FAGM			
25/10/1999	ZS-JJB	FAGM	FAUP		FAGM	1 + 7	1	
25/10/1999	ZS-JJB	FAUP	FYOG	384 L / 101.5 Gall	FAUP	1 + 7	1	4
29/10/1999	ZS-JJB	FYOG	FYOG	310 L / 81.9 Gall	FAAB	1	1	
29/10/1999	ZS-JJB	FYOG	FAGM			1 + 7	1	4
01/11/1999	ZS-OJY	FAGM	FYOG	200 L / 52.84 Gall	FAGM	1 + 9	2	4
05/11/1999	ZS-OJY	FYOG	FYOG	590 L / 155.9 Gall	FAAB	1	2	
05/11/1999	ZS-OJY	FYOG	FAGM			1 + 9	2	4
07/11/1999	ZS-OJY			751 L / 198.4 Gall	FAGM			
08/11/1999	ZS-OJY	FAGM	FYOG			1 + 7	1	4.1
11/11/1999	ZS-OJY	FYOG	FYOG	652 L / 172.3 Gall	FAAB	1	1	
12/11/1999	ZS-OJY	FYOG	FAGM			1 + 7	1	3.9
14/11/1999	ZS-JJB			494 L / 130.5 Gall	FAGM			
15/11/1999	ZS-JJB	FAGM	FYOG		FAGM	1 + 9	1	3.5
15/11/1999	ZS-JJB	FYOG	FYOG	588 L / 155.4 Gall	FAAB	1	1	
17/11/1999	ZS-JJB	FYOG	FAGM	336 L / 88.8 Gall	FAAB	1 + 9	1	3.5
21/11/1999	ZS-OJY	FQIN	FALA	859 L / 226.9 Gall	FALA	?	1	
22/11/1999	ZS-OJY	FAGM	FYOG	65 L / 17.2 Gall	FAGM	1 + 7	2	4.25
26/11/1999	ZS-OJY	FYOG	FYOG	577 L / 152.4 Gall	FAAB	1	2	
26/11/1999	ZS-OJY	FYOG	FAGM			1 + 7	2	4.1
29/11/1999	ZS-OJY	FAGM	FYOG	652 L / 172.3 Gall	FAGM	1 + 8	1	4.3
03/12/1999	ZS-OJY	FYOG	FYOG	565 L / 149.3 Gall	FAAB	1	1	
03/12/1999	ZS-OJY	FYOG	FAGM			1 + 8	1	3.8
06/12/1999	ZS-OJY	FAGM	ACCIDENT	664 L / 175.4 Gall	FAGM	1 + 9	2	

1.18.11 When the total fuel uplift for ZS-OJY for the direct flights to Oranjemund were calculated it came to 831.8 gall. The total time booked by the pilots for these flights came to 20.82 hours. The average fuel consumption for this aircraft could thus be calculated at 831.8 gall/20.82 hours = 39.95 gall/hr. or 19.97 gall/hr. per engine. If these values are considered then the calculated amount of 129.186 gall for the flight to Oranjemund was too low.

1.18.12 The typical mass and balance of each of these flights from Rand Airport to Oranjemund were calculated. The actual masses of the persons onboard each flight was used, but to reach a reasonably accurate figure two assumption were made. It was assumed that the fuel tanks were filled to capacity each time the aircraft took-off from Rand Airport to Oranjemund. This assumption was based on several fuel uplifts, which were close to the full capacity of the fuel tanks like for example the uplift on 21 November 1999 at Lanseria of 226.9 gall (total capacity of fuel tanks 235 gall) and the "top-up" at Rand Airport the next morning. The second assumption was that the pilot and passengers each took 10 kg. baggage onboard. The mass of the baggage retrieved from the wreck was more than 10 kg. per person (about 14 kg per person).

1.18.13 The mass and balance calculations are attached to this report as annex B. The following table reflects the calculated total ramp mass of the aircraft on each flight from Rand Airport to Oranjemund:

Date	Aircraft	Ramp Mass in lbs.
04/10/1999	ZS-JJB	7321.3
18/10/1999	ZS-OJY	7747
25/10/1999	ZS-JJB	7001.7
01/11/1999	ZS-OJY	7746.7
08/11/1999	ZS-OJY	7398.5
15/11/1999	ZS-JJB	7314.9
22/11/1999	ZS-OJY	7427.1
29/11/1999	ZS-OJY	7434
06/12/1999	ZS-OJY	7790.72

1.18.14 If the above ramp masses are considered it indicate that only on one flight on 25 October 1999, the ramp mass of the aircraft was less than the maximum ramp mass of 7045 lb.

1.19 Useful or effective investigation techniques.

1.19.1 It is believed that analysis of the organisational and systemic circumstances surrounding this accident using the Reason Model contributed significantly to the investigation team's understanding of these circumstances, and the capacity to make recommendations aimed at correcting organisational deficiencies and enhancing system defences.

2 ANALYSIS

2.1 Introduction

2.1.1 The summary of events leading to this accident should be taken back to about the beginning of 1998 when operations inspections were carried out at the carrier by the CD:CAA. At that time it was identified that anomalies existed with their Air Law documentation, loadsheets and Operations Manual. These noted problems were early signs of an operation that was not functioning, as it should have.

2.1.2 The process relating to airworthiness of the accident aircraft started when it was imported into South Africa in May 1999. The documentation relating to the airworthiness of the aircraft was not properly updated to reflect the true status of the aircraft. The CAA airworthiness inspector did not identify the errors in this documentation during his inspection. Modifications such as the Vortex Generator

Kit and the Nacelle Fuel System were not properly documented or taken into consideration at the time when the airworthiness inspections of the aircraft were carried out. The flight performance flight test data was not accurate, thus it was impossible to determine whether the aircraft was able to perform as it was prescribed to perform. It was also impossible to determine what the true effect of the fitted vortex generators really was on the specific aircraft. The airworthiness inspector signed the approval for the issue of the Certificate of Airworthiness and the final signature was obtained from his regional inspector.

2.1.3 The operators that the investigation team contacted in relation to the flying characteristics of the aircraft agreed that this type of aircraft usually does not maintain height under full load conditions with one engine inoperative. The airspeed is critical, and one needs to lower the nose for the airspeed to increase to the prescribed value. This is very difficult to accomplish if the aircraft is at a very low altitude when the engine fails. The exhaust pipe segment most probably failed just after rotation during the take-off, which meant that the pilot was unable to attain the prescribed airspeed value of 106 knots. He needed to retract the undercarriage and flaps and accelerate to the 106 knots airspeed value when he had no height to trade off for speed and a reduction in engine power.

2.1.4 It has been suggested that with hindsight the pilot should have made every attempt to keep the engine operating in order to produce as much power as possible. The problem with this suggestion is that it is difficult to determine what the exact behaviour of the engine was when the exhaust pipe segment broke away and the engine started losing power. Whether the engine failed completely or just lost power was impossible to determine. Pilots are trained to follow certain procedures relating to the specific aircraft they are operating during engine failure and in this case it seems that the pilot followed the recommended procedures accurately in the very limited time he had available before impact. One must bear in mind that the pilot had a similar experience about 2 years before the accident where he had a partial engine failure after take-off and he did not feather the engine during this incident. The pilot reported an engine failure of the right-hand engine and a witness stated he could see the blades of the propeller.

2.1.5 Based on experience of a similar failure, the engine manufacturer’s representative was of the opinion that one would expect about a 40% to 50% power reduction when an exhaust pipe segment failure occur. The experiment performed during the ground run on the similar engine also suggests that the engine was delivering reduced power. It is possible that when the witness saw the aircraft and he saw the blades of the propeller that the pilot was already in the process of securing the engine. With an overload condition added to the engine failure, it would worsen the situation substantially.

2.1.6 Considering reasons why the aircraft was not capable of maintaining altitude the following was considered: The pilot requested a left-hand turn back to Runway 29, which was the direction he should have turned with the right-hand engine inoperative. Although the pilot requested this turn he did not enter it. The accident site was on an extended line from the runway, suggesting the pilot most probably did not have time or altitude to enter the turn. The aircraft was seen and it impacted in a nose high, right-hand wing low attitude. This was most probably due to him manoeuvring the aircraft at the last moments to avoid ground obstacles. Whether the pilot maintained balanced flight was impossible to determine, but most probably did, taking into account his experience. The nose of the aircraft was high at impact, but that was probably not the case for the whole flight. Taking all this into consideration the most probable reason why the aircraft was not able to maintain altitude was the overloaded situation.

2.1.7 The flight folio of the aircraft was not completed as was required and this had a specific implication on the maintenance of the aircraft. There is evidence that the aircraft had a defect on the right-hand engine after the mandatory periodic inspection was certified on 23 September 1999. This defect should have been entered in the flight folio of the aircraft and certified as rectified after the repair by the Aircraft Maintenance Organisation. Additionally, the flight folio also keeps record of the hours flown and is used to determine when the mandatory periodic inspection is due. In this case evidence was found that the mandatory periodic inspection time was overflown on a previous occasion. This is also an indication of the organisational culture of poor compliance with Civil Aviation Regulations that prevailed in the operator.

2.1.8 The definition of flight time and how it is recorded is another point of contention in the South African aviation industry. The Civil Aviation Regulations are clear that it should be the actual time from when the aircraft moves under its own power for the purposes of flight, until the aircraft come to a standstill after the flight. In most cases hobbsmeter readings are used, however the hobbsmeters are connected in a number of different ways. Depending on the application of the aircraft, they are either connected to the master switch, engine oil pressure switch, landing gear selector switch or a pressure switch on the side of the fuselage. A hobbsmeter connected to the engine oil pressure switch would most probably provide the most accurate flight time readings.

2.1.9 The pilots should thus also record flight time according to the Civil Aviation Regulations in their logbooks. If the situation of this aircraft was considered (refer to section 1.6 of this report) the hobbsmeter reading was thus not providing the actual flight time as defined in the Civil Aviation Regulations. The calculated flight time for the aircraft since the previous mandatory periodic inspection was 101:45 airframe hours (not considering the 3.75 hours that the aircraft had overflown its previous mandatory periodic inspection). This would imply that the aircraft had effectively exceeded its due time for the next mandatory periodic inspection before the flight had started, which implies that the aircraft was technically unserviceable and the Certificate of Airworthiness was invalid.

2.1.10 The problematic situation with the use of hobbsmeters (however they are connected) to record flight time is that this is an accepted practice in the South African aviation industry. Pilots record the flight time in the flight folio of the aircraft using the hobbsmeter reading and many aircraft mandatory periodic inspections are carried out according to the hobbsmeter readings.

2.1.11 The failure analysis of the exhaust pipe segment suggests that it was due to a fatigue crack which propagated over a period of time. The final failure occurred over the last part of the crack and caused the large loss of exhaust gas, which caused the engine to either loose power or fail. The engine manufacturer ascribed the cause of the exhaust pipe segment failure to a combination of improper installation and maintenance together with a lack of proper pre-flight and periodic inspections. The crack in the exhaust system was in such a position that it was nearly impossible to see during a pre-flight inspection when the engine cowls were in place. During the mandatory periodic inspection in September 1999 the exhaust system was inspected and signed off. If the crack were present during the inspection it would have most probably been noticed and repaired. If the crack was very small during the inspection there is a possibility that it would not have been noticed. Towards the end of September 1999 and the beginning of October 1999 the density controller and the turbocharger was overhauled. Due to the work being carried out in that area one would expect that such a crack would be noticed, but the crack in the second aircraft's exhaust system was identified by the investigator-in-charge while the turbocharger was overhauled and similar work was being carried out. Effectively when the turbocharger is removed, the exhaust manifold system from the cylinders need not to be disturbed, it is thus not a requirement to inspect the exhaust system during the replacement of the turbocharger. However in the light of the manufacturer's service instructions one would expect that an inspection would be carried out of the exhaust system. Whether the exhaust system was properly tightened as described in the manufacturer's service letters is impossible to determine.

2.1.12 The above mentioned maintenance was completed on 5 October 1999, about two months before the accident and about 80 to 90 flying hours before the accident. It is possible that the crack had formed and propagated during this time and did not exist at the time of the mandatory periodic inspection or when the work on the turbocharger system was performed. It was possible that the crack could have been identified if the aircraft had been withdrawn from service for the next mandatory periodic inspection before this flight.

2.1.13 The overloading of the aircraft was not an isolated case. The original quotation for the flights from Rand Airport to Oranjemund could be considered as a quotation of a flight using an overloaded aircraft. The initial idea was to fuel stop at Upington, but by the second flight a direct route was followed. For the flights to Upington, the aircraft would have been overloaded in any case if it had been loaded according to the prescribed fuel limits in terms of the CATS-OPS 91.07.11 and 91.07.12.

2.1.14 Neither the pilot nor the operator made sure that the aircraft was loaded within the limits prescribed for the aircraft. The baggage was not weighed and the passengers were not weighed either. During the on-site investigation of the accident as much of the baggage as possible, was recovered from the stream, dried out and then weighed. The mass determined in this way was the lowest possible load onboard the aircraft. Some bits of clothing washed down the stream and the actual mass of small items like pillows and food the passengers brought with them onboard was impossible to determine. Thus the mass of the aircraft could have been even more. As the circumstances of the accident illustrated, the aircraft was unable to maintain altitude when an engine became inoperative.

2.1.15 It is believed that the re-instatement of the confidential hazard reporting scheme would provide an additional and confidential avenue for the reporting of factors, which have the potential to impact negatively on flight safety. Schemes of this type are particularly useful in the context where perceptions exist regarding the negative career consequences associated with reporting such problems via normal official channels.

2.1.16 It is considered that the processes of the Air Services Licensing Council for issue of Air Services Licences to applicants with limited flight operations management experience may benefit from review.

2.2 Methodology

2.2.1 Experience has shown that most accidents usually result from a complex interaction of factors, some of which are within the control of those at the accident site, and many of which are not. Contemporary investigation techniques are oriented towards the systemic investigation of the organisational, regulatory and cultural contexts in which an accident occurs.

2.2.2 Professor James Reason developed an analytical model, known as "The Reason Model" and may be used to identify safety deficiencies within organisations. This model is attached to this report as Appendix D.

2.3 Overview

As is the case with most industrial mishaps, the accident at Rand Airport was the result of a complex interaction of circumstances, precipitated by an unsafe act performed by a front line operational employee.

The objective of this investigation was not to attribute blame or liability to any individual or organisation, but rather to learn from this accident in order to prevent similar occurrences in the future. As such, it is necessary to consider not only the unsafe act performed by the employee, but also the circumstances which may have encouraged this individual to act as they did, including the nature of the systemic and environmental factors which permitted their action to have such serious and immediate consequences.

In order to achieve this, the investigation team has applied methodology derived from the Reason Model to analyse the circumstances of the accident.[1] Causal factors were classified into the following categories for analysis:

- Absent or failed defences;
- Active failures;
- Task/Environmental conditions;
- Organisational factors; and
- System factors.

Each of these categories is addressed below.

2.3.1 **Absent or failed defences**

Defences are elements of a system which are intended to prevent or mitigate the effects of hazards in the operational environment. These hazards can include the consequences of a human act or component failure during an incident. The defences which should have been in place and worked to prevent this accident include:

- Civil aviation regulations relating to calculation of mass and balance of aircraft loads, and maximum load of the aircraft;
- Standard Operating Procedures relating to calculation of mass and balance of aircraft loads, and maximum load of the aircraft;
- The training, experience and professional qualifications of the operating pilot;
- Effective flight operations standards supervision at the carrier;

- Regulatory system oversight intended to ensure the effectiveness of flight operations standards and supervision within aviation operations.

2.3.2 Active failures

Active failures are unsafe acts, which are errors or violations of standards or procedures committed by individuals or groups, which directly contribute, to the cause of the accident. They are usually committed in close proximity to the time and place of the accident. The active failures identified within this accident sequence include:

- The pilot's action in not weighing passengers and baggage for the accident flight (a violation);
- The pilot's action in not calculating an actual mass and balance for this flight (a violation);

2.3.3 Task/Environmental conditions

Task and environmental conditions are situational conditions, which have a direct influence on human or equipment performance and are in existence immediately prior to or at the time of the accident. The task and environmental conditions, which contributed to this accident, are as follows:

- The overloading of the aircraft;
- The fact that it was an accepted practice at this operator to 'bend' rules and SOP's in order to get tasks done;
- The crack in the right-hand engine exhaust manifold.
- The pilot's judgement and airmanship skills;
- A low level of effective flight operations standards supervision at this operator.

2.3.4 Organisational/System factors

These are failures within the organisation/s and system/s involved in the accident, which may have had direct influence over the identified task, and environmental conditions, which contributed to the accident. These factors may lie undetected for a long time within an organisation or system and their impact may only become apparent once they combine with local workplace factors (Task/Environmental conditions) and active failures to breach the defences of a system and cause an accident. The organisational factors which contributed to the occurrence of this accident are many. They include:

- The lack of an established 'safety culture' at this operator;
- A low level of flight operations standards knowledge, experience and professional flight operations supervision at this operator;
- The lack of an effective flight training structure and regime at this operator;
- A professional culture amongst commercial pilots at this level of the industry to "get the job done". Amongst other things, this culture is reinforced by the knowledge that there are generally too many pilots and too few jobs to go around, so that a perception exists that those who do not get the job done may have difficulty in retaining their jobs or finding alternate employment;

- Significant commercial/competitive pressure at this level of the commercial aviation industry. This in turn produces pressure on operators to minimise overheads. This can influence decisions on the provision of training and operational supervision for staff; It also produces pressure regarding the appropriate balance of at times incompatible goals, such as safety and profitability;
- Deficiencies in the supervision of this operator with regard to airworthiness and flight operations surveillance by the CD:CAA and CAA can be linked to organisational change, culture change and staff shortages within the CD:CAA and CAA over the 14 months preceding this accident. The workload associated with assimilation of these changes, and the associated staffing and resources issues identified above no doubt contributed to the deficiencies identified during the investigation.
- Insufficient integration of safety management capacity of applicants in licensing council process.

3 CONCLUSIONS

3.1 Findings

3.1.1 The aircraft took off from Rand Airport on a charter flight to Oranjemund and about 2 minutes after take off impacted the ground, fatally injuring all of the ten occupants.

3.1.2 An instrument flight rules flight plan was filed for a flight to Oranjemund without any intermediate landing points.

3.1.3 The pilot was the holder of a valid commercial pilot licence with an instrument rating and the aircraft type endorsed in his logbook.

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

3.1.5 The only method to determine the airframe hours at the time of the accident was to use times logged by pilots and aircraft movement records. The total amounted to 101:45 hours from the last mandatory periodic inspection, but it was possible that the hobbsmeter only indicated about 91.58 hours.

3.1.6 The previous mandatory periodic inspection was overflown by 3.75 hours and the last flight prior to the mandatory periodic inspection was an illegal flight (Certificate of Airworthiness lapsed).

3.1.7 Different hours were logged in the pilot's logbook than were logged in the aircraft's flight folio.

3.1.8 A deviation from the defined "flight time" is detected in the industry due to the use of hobbsmeters and the way the hobbsmeters are connected to record the "Flight time".

3.1.9 The last record of maintenance work carried out on the turbocharger system of the right-hand engine was completed on 5 October 1999 after the mandatory periodic inspection was certified, but the work most probably did not disturb the exhaust manifold system.

3.1.10 The aircraft was fitted with a vortex generator kit and nacelle fuel tanks that were not indicated on the equipment checklist or in the logbooks of the aircraft as modifications.

3.1.11 An error was detected on the last mass and balance report.

3.1.12 It was calculated that the aircraft was operated 785.715 lbs. in excess of its maximum certified take-off mass.

3.1.13 Calculations made by the investigating team of typical mass and balance conditions of the previous flights to Oranjemund suggests that the aircraft was overloaded on most of the flights to Oranjemund.

3.1.14 A loadsheet produced as the loadsheet for the accident flight did not conform to the prescribed format and requirements.

3.1.15 The performance flight test data report submitted to the CAA, was found to be incorrect and was accepted without being evaluated by the CAA.

3.1.16 The aircraft logbooks did not make provision for the recording of modifications incorporated on the aircraft.

3.1.17 It was observed during the on-site investigation that the right-hand propeller was in a feathered pitch position, which suggest that the pilot had secured the engine.

3.1.18 The weather was fine at the time of the accident.

3.1.19 In his communications with Rand Tower the pilot declared an emergency after take-off. He reported a right-hand engine failure.

3.1.20 The pilot was positively identified by DNA tests. The cause of death of the pilot was noted as “fracture of the base of the skull compounded by acute severe burns”.

3.1.21 This was not considered as a survivable accident.

3.1.22 The engines were subjected to dismantling inspections. On the left-hand engine evidence was found that the engine was operational during the impact. The right-hand engine lost power due to a failure in the exhaust system that feed the turbocharger. A small fragment of dirt was also found in the number six cylinder fuel nozzle of the right-hand engine.

3.1.23 A similar crack was found on another aircraft’s exhaust system at a similar position. Both the failed exhaust pipe segments were metallurgically analysed and the crack propagation in the pipe material was attributed to fatigue.

3.1.24 The manufacturer ascribed the reason for the exhaust failure to improper installation of the exhaust system and maintenance of the exhaust system. The investigation team was also referred to several Service Instructions released by the manufacturer.

3.1.25 The operator was issued a Class II Air Service Licence, but their operating certificate had expired on 29 November 1999 and was thus not valid at the time of the accident.

3.1.26 The operator had no formal safety management program in place.

3.1.27 Several deficiencies existed in the operator’s personnel and operational record systems.

3.1.28 The familiarity of the staff of the operator was generally poor with reference to their operational documentation.

3.1.29 The Civil Aviation Authority inherited an understaffed organisation from the CD:CAA, particularly in the flight operations inspections area and had difficulty in filling the vacancies.

3.1.30 Several anomalies were identified in the CD:CAA and CAA’s role as the regulator. These involved apparent inadequacies in regulatory oversight of the aircraft operator concerned, including the process involved in issuance of the Aircraft Operations Certificate and oversight of flight operations standards.

3.1.31 Several anomalies were noted in the CAA aircraft file with relation to the airworthiness inspection of the aircraft when it was imported into the country.

3.1.32 The confidential hazard reporting system that existed in South Africa was discontinued.

3.1.33 The Aircraft Maintenance Organisation was in possession of a valid Certificate of Approval, but some anomalies were noted on the CAA Aircraft Maintenance Organisation's file.

3.1.34 The quotation for the flights to Oranjemund issued by the operator could be considered as necessitating that flights were flown by their aircraft in an overloaded condition.

3.1.36 Evidence suggests that it was common practice at this operator to ignore requirements for an accurate calculation of passenger and baggage weight and aircraft weight and balance when preparing for flights.

3.2 Probable Causes

3.2.1 The precipitative cause of this accident was the failure of the exhaust pipe segment, which caused the right–hand engine to lose power/fail.

3.2.2 The overloaded condition of the aircraft was thus a highly significant contributory factor.

3.2.3 The pilot operating the aircraft in an overloaded condition is regarded as a significant contributing factor.

3.2.4 The company's lack of flight operations management experience, professional flight standards supervision and an operational safety management program are regarded as significant contributing factors.

3.2.5 The anomalies noted in regulatory oversight of the operator (airworthiness and flight operations surveillance) by the CD:CAA and CAA are regarded as possible contributing factors.

4 SAFETY RECOMMENDATIONS

4.1 A Maintenance Advisory Notice was drafted and the airworthiness section of the CAA was requested to distribute it as soon as possible to alert Aircraft Maintenance Organisations of the possibility of cracks on the exhaust manifolds of these type of engines.

4.2 The operator should be inspected with reference to the deficiencies identified during the investigation and noted in this report. They should also be inspected with reference to compliance of their Operations Manual.

4.3 It is recommended that the CAA make urgent efforts to provide efficient staffing levels in the airworthiness and flight operations departments.

4.4 The airworthiness department procedures should be reviewed in terms of how they deal with the processing and accurate documentation of aircraft during the issuance of a certificate of airworthiness. Particularly attention should be given to the performance test flight and the equipment checklist including the documentation of mass and balance status of the aircraft.

4.5 It is recommended that the CAA develop and implement a data base system which will allow staff to more systematically record, track and monitor the performance of operators with respect to compliance with airworthiness and flight operations inspection requirements.

4.6 The flight operations department should review their procedures of dealing with operators with reference to the issuance of Aircraft Operating Certificates and safety oversight. In particular, this review should consider the extent of safety oversight activities necessary when dealing with operators which may be lacking in flight operations management experience.

4.7 It is recommended that requirements for flight operations training and standards supervision be reviewed with a view to strengthening the requirement for operators to provide such training and supervision to operational personnel.

4.8 It is recommended that the CAA establish a requirement for commercial aviation operators to implement and support an effective operational safety management program.

4.9 It is recommended that the CAA work closely with the development of training processes and materials to assist commercial operators to implement an effective operational safety management program. This is to ensure adequate flight operations management capacity exist within commercial operators.

4.10 It is recommended that a process be implemented to ensure the involvement of a company's manager of flight operations in the creation and maintenance of the organisation's Operations Manual.

4.11 It is recommended that the process of production, approval and maintenance of aviation companies operational manuals and other documentation be reviewed by the CAA. It must specifically be monitored that a company's operational personnel are familiar with the contents of the organisation's Operations Manual.

4.12 It is recommended that the processes employed by the Air Services Licensing Council for the issue of Air Services Licences to applicants with limited flight operations management experience be reviewed; in particular these processes should be reviewed to ensure that successful applicants are required to establish and maintain an appropriate level of flight operations management experience for the purpose of holding an Air Services Licence.

4.13 It is recommended that consideration be given to the re-establishment of a Confidential Hazard Reporting System within the South African aviation industry.

4.14 It is recommended that the CAA carry out regular spot checks with weighing equipment as a means of combating the culture of operating overloaded aircraft.

4.15 It is recommended to the management of commercial operators to ensure that they themselves as well as their operational staff are familiar with the contents and requirements of their operations manuals.

4.16 It is recommended that in a safety promotion drive targeted at pilots, the dangers of operating overloaded aircraft be highlighted.

4.17 It is recommended to the management of commercial operators and private aircraft owners ensure that they adhere to the mandatory periodic inspection time limits of aircraft and components in order that defects which are not readily visible could be identified and corrected.

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5. APPENDICES :

5.1 **Appendix A** (Refer to next page).

<u>Aircraft accident Piper PA 31: ZS-OJY on 6/12/99 – Rand</u>

Aircraft accident wreckage distribution diagram

1

30m

N0TE: N0T TO SCALE

22

45 m

3

25 m

13 m

20 m

290° M

5.2 **Appendix B**

5.2.1 Introduction

The exhaust pipe segment under investigation was retrieved from an aircraft (Registration ZS-OJY, aircraft type Piper PA31/350 Chieftain)) that was involved in an accident shortly after take-off. The request was to evaluate the fracture surface of the exhaust pipe flange, to determine a possible cause of failure. The fractured exhaust pipe flange connects the exhaust pipe manifold onto the waste gate assembly, and originates from the right-hand engine of the aircraft.

A second exhaust pipe, with a similar cracked flange and retrieved from a similar aircraft (Piper Chieftain), was also supplied for investigation. Due to the seriousness of the aircraft accident, it was decided to keep its fractured exhaust pipe segment (referred to as "fractured exhaust pipe flange”) intact for possible later reference, hence using the second pipe (referred to as ”reference pipe") as reference in the investigation. The equivalent position of the latter pipe as well as its similarity with regard to the cracked flange radius area suggest that its result can be effectively used to determine a possible cause of failure of the exhaust pipe segment retrieved from the crashed aircraft.

5.2.2 **Visual Inspection**

Figure 1 shows the general appearances of the fractured exhaust pipe flange section and the reference pipe. The fractured exhaust pipe flange, the latter forming the connection with the waste gate assembly via a U-shaped clamp, is clearly visible.

Various angled views of both the fractured exhaust pipe segment flange and the reference exhaust pipe section are shown in figure 2. The crack of the fractured exhaust pipe flange probably originates in the pipe flange radius area and propagated around approximately 75% of the pipe circumference prior to eventual fracture of the outer mating surface ring. Rejoining the fracture surface clearly indicates that part of the pipe material adjacent to the flange-mating ring is missing. The reference pipe reveals a similar crack in the pipe flange radius, except that it propagated only approximately half way around the pipe circumference, and that fracture of the flange mating ring section has not yet occurred.

Figure 3(a) shows a front inner view of both pipe sections. In both instances the crack on the inner pipe flange radius is visible, indicating that the flange radius cracked and propagated along the circumference and over the entire pipe wall width. Close-up views of both fracture surface appearances and the surfaces of adjacent areas are shown in figure 3(b). The fracture surface of the fractured exhaust pipe segment flange indicates oxide and/or debris coverage of the fracture surface as well as debris buildup on the outer surface adjacent to the fracture surface. Although some vague evidence of beach lines or clamshell marks is visible on the fracture surface area adjacent to the flange ring, most of the fracture surface appearance is obscured by oxide formation or debris build-up. The reference pipe not only indicates the same fracture surface disguise due to oxidation and debris build-up, but it also indicates crack branching. The latter is to such an extent, that where branching cracks are reunited, entire triangular sections of the pipe wall can break out, leaving a substantial hole in the flange radius area behind. This corresponds with the visible missing pipe wall sections in the fractured pipe flange radius area, as was referred to in figure 2.

The cross sectional fracture surface appearance of the fractured exhaust pipe segment flange ring (i.e. the mating surface between the manifold and waste gate assembly) is shown in figure 4 (see next page). This fracture surface has a “sheared" appearance with a distinct different colour, i.e. a lightly discoloured "metallic" colour that differs from the oxide- and debris build-up as referred to in figure 3(b). Oxide- or debris build-up is only visible on the outer surfaces of the flange, indicated by the dark discoloured outer edges.

In an effort to reveal the fracture surface appearance at both crack ends of the reference pipe, cross sectional samples were sectioned from these areas. The latter samples were subsequently opened to reveal both crack tips. These results are shown in figure 5 (see next page), indicating that the crack width equals the flange pipe wall width above the welding attachment of the flange section to the main pipe bend. The fracture surface appearance at one end of the crack tip reveals clamshell marks or beach lines, indicating that the crack propagated in that area due to fatigue. The opposite end of the crack tip reveals visible herringbone lines, indicating a mixed mode fracture with the crack propagation rate higher at that crack end. Due to the severe oxidation and/or debris build-up on the remaining crack surfaces, the origin of the fatigue crack can not be determined.

5.2.3 Scanning Electron Microscope (SEM) Evaluation

The reference pipe fracture surface was subjected to a SEM evaluation. A low magnification fracture surface appearance is shown in figure 6(a). After partial cleaning of the fracture surface with diluted inhibited acid, the cleaned fracture surface appearance indicates some directionality attributed to the sheet manufacturing process from which the pipe section is manufactured. An oxide- or debris layer obscures the visibility of the remainder of the fracture surface. This corresponds with the visible oxide- and/or debris layer as indicated in figure 3(b).

Figure 6(b) shows an enlarged fracture surface appearance of the existing crack surface of the reference pipe. The fracture surface appears to be pitted and damaged by the constant high temperature present during engine operation. Due to the latter, any evidence on the fracture surface is obscured or destroyed.

Opening both crack tip ends created "new" fracture surfaces adjacent to the ends. Examples of these fracture surface appearances are shown in figure 6(c), indicating a dimpled ruptured fracture surface with both partial internal cracks and dimples due to tearing visible. The latter suggests a material of good ductility.

5.2.4 Microstructure

Sectioning, polishing and etching of a reference pipe sample, including a cross section of the fracture surface, reveals a microstructure as is shown in figure 7. The microstructure consists of austenite, indicative of a material applicable for intermittent high temperature applications. The average hardness of the microstructure is $HV212_{5kg}$ (Vickers Hardness) and is typical for an austenitic microstructure.

An oxidized layer and/or debris layer build-up is also visible on both the fracture surface and the outer surface adjacent to the crack. Partial penetration of this layer on austenite grain boundaries is also evident.

5.2.5 Discussion

The austenitic microstructure of the reference pipe (figure 7) suggests that the exhaust pipe segment flange sections are manufactured from an austenitic type stainless steel. This is a material frequently used for components subjected to intermittent high temperatures as is experienced in exhaust applications. The pipe material is thus normal for such an application. The microstructure also corresponds with the "newly" created fracture surface (figure 6(c)) which typically indicates the fracture surface of a ductile material.

The position of both cracks, i.e. in the pipe flange radius area (figure 1), as well as the similarities of both fracture surface appearances (figures 2, 3(a) and (b)), suggests that the formation of both cracks can be attributed to the same reason. The fracture surface appearance of the fractured pipe flange adjacent to the flange mating ring (figure 3(b)) as well as the crack tip ends of the reference pipe (figure 5), i.e. clamshell marks and herringbone lines, indicate that crack formation and propagation in both pipes can be attributed to fatigue. Due to oxidation- and/or debris build-up on the fracture surfaces of both pipes (figures 3(b), 6(a) and 7) the crack origin could not be detected, but appears to be in the radius area of the flange section of the exhaust pipe segment. The fatigue crack, however, propagated along the circumference and over the entire pipe wall width during engine operation with simultaneous partial crack branching (figures 3(b) and 5). When the latter cracks reunited, sections of the pipe flange radius wall were completely broken out (figures 2 and 3(a)), creating the potential for increased exhaust gas leakage. Due to the latter oxidation and/or gas erosion (figure 6(b)), as well as exhaust gas debris build-up on existing crack surfaces and adjacent outer pipe surfaces (figures 3(b), 6(a) and 7) now occurred.

The fracture surface appearance of the fractured pipe flange mating surface ring (figure 4) reveals a distinct colour difference if compared with the remaining fracture surface appearances of both pipe flange sections (figure 3(b)). The light colour indicates short time fracture surface oxidation due to the presence of a higher temperature while not permitting the build-up of any oxidation- and/or exhaust gas debris layer yet. This suggests that the fracture surface was present for a short period of engine operation only. The visible build-up of oxidation and/or debris on the outer surfaces on both sides of the cross sectional mating ring fracture surface (figure 4) indicates that those surfaces were subjected to hot exhaust gasses during engine operation prior to the cross sectional fracture of the mating surface ring.

It is consequently suggested, that due to thermal- and possible also vibration stresses to which the entire manifold system is subjected during engine operation, a fatigue crack was nucleated in the flange radius area adjacent to the clamp fixation with the waste gate of the exhaust system (figure 1). Due to these thermal- and vibration stresses, the nucleated fatigue cracks propagated along the flange radius circumference. Occasional branching/reuniting of the propagating crack (figure 5) created crack surfaces with triangular shaped pipe wall sections in the flange radius area missing (figures 2, 3(a) and (b)). These crack surfaces and triangular holes were now exposed to exhaust gas oxidation and possible erosion, thus building-up oxidation layers and/or exhaust gas debris layers on the crack surfaces and adjacent exhaust pipe segment wall surfaces (figures 3(b) and 7). The oxidation and/or debris build-up damaged both fracture surfaces (figures 6(a) and (b)) to such an extent that no fatigue evidence was visible. Exceptions to the latter are both crack tips on the reference pipe crack (figure 5) and the vague fatigue striations adjacent to the fractured pipe flange mating surface ring (figure 3 (b)). Due to the presence of thermal stresses and vibration stresses, the propagating fatigue crack eventually sheared the entire cross section of the flange mating surface ring section (figure 4). The latter was then subjected for a short time to higher temperatures only, hence discolouring it lightly. This sudden fracture of the flange mating surface ring also resulted in the pipe now being bent sideways by outward deformation of the remaining pipe flange circumference material (figures 1 and 2). This sideways deformation is evident if the mating surface is placed on a flat surface, indicating that the crack surfaces are now well apart. The sudden fracture of the mating surface ring and opening of the crack would have immediately intensified any exhaust gas blow out or leakage from that area.

5.3 **Appendix C**

5.3.1 The following mass and balance calculations were calculated with the actual masses of the pilot and passengers and on the following assumptions:

- the fuel tanks were filled to capacity on each flight.
- The pilot and passengers each had 10 kg of baggage with them on that particular flight.

MASS AND BALANCE CALCULATIONS

ZS-JJB on 04/10/1999	Quantity [U.S Gall.]	Weight [lbs.]	Arm [in.]	Moment [lb. Ins.]
Empty Weight (incl. Full oil)		4521.6	121.9	551142.7
Fuel (Inboard)	106	636	126.8	80644.8
Fuel (Outboard)	76	456	148	67488
Fuel (Nacelle)		0		0
Pilot 1		143.3	95	13613.5
Passenger 1		242.51	95	23038.45
Passenger 2		130.07	132	17169.24
Passenger 3		138.69	132	18307.08
Passenger 4		110.23	163.5	18022.61
Passenger 5		138.69	163.5	22675.82
Passenger 6		165.35	195	32243.25
Passenger 7		110.23	195	21494.85
Passenger 8		143.3	229	32815.7
Passenger 9		143.3	247	35395.1
Baggage nose		220	19	4180
Baggage rear			192	0
Standard cooler box		22	255	5610
Other				0
Other				0
TOTAL WEIGHT AND MOMENT		**7321.3**		**943841.1**
C of G position			**128.9**	

Passenger Seating

Front of Aircraft

Pilot 1 = 65 kg = 143.3 lbs   CS = 110 kg = 242.51 lbs.

ABE = 59 kg = 130.07 lbs   ABU = 62 kg = 138.69 lbs

TD = 50 kg = 110.23 lbs   UR = 62 kg = 138.69 lbs

FS = 75 kg = 165.35 lbs   NG = 50 kg = 110.23 lbs

RM = 65 kg = 143.3 lbs   MS = 65 kg = 143.3 lbs

Rear of aircraft

MASS AND BALANCE CALCULATIONS

ZS-OJY on 18/10/99	Quantity [U.S Gall.]	Weight [lbs.]	Arm [in.]	Moment [lb. Ins.]
Empty Weight		4594	124.1	570071.9
Fuel (Inboard)	106	636	126.8	80644.8
Fuel (Outboard)	76	456	148	67488
Fuel (Nacelle)	54	324	142.8	46267.2
Pilot 2		172	95	16336.2
Passenger 1		242.5	95	23038.45
Passenger 2		130.1	132	17169.24
Passenger 3		138.7	132	18307.08
Passenger 4		110.2	163.5	18022.61
Passenger 5		138.7	163.5	22675.82
Passenger 6		165.4	195	32243.25
Passenger 7		110.2	195	21494.85
Passenger 8		143.3	229	32815.7

Passenger seating

Front of Aircraft

Pilot 2 = 78 kg = 171.96 lbs   CS = 110 kg = 242.51 lbs.

ABE = 59 kg = 130.07 lbs   ABU = 62 kg = 138.69 lbs

TD = 50 kg = 110.23 lbs   UR = 62 kg = 138.69 lbs

FS = 75 kg = 165.35 lbs   NG = 50 kg = 110.23 lbs

RM = 65 kg = 143.3 lbs   MS = 65 kg = 143.3 lbs

Rear of aircraft

Passenger 9	143.3	247	35395.1
Baggage nose	220	19	4180
Baggage rear	0	192	0
Standard cooler box	22	255	5610
Other			0
Other			0
TOTAL WEIGHT AND MOMENT	**7747**		**1011760**
C of G position		**130.6**	

MASS AND BALANCE CALCULATIONS

ZS-JJB on 25/10/99	Quantity [U.S Gall.]	Weight [lbs.]	Arm [in.]	Moment [lb. Ins.]
Empty Weight		4521.6	121.9	551143
Fuel (Inboard)	106	636	126.8	80645
Fuel (Outboard)	76	456	148	67488
Fuel (Nacelle)		0		0
Pilot 1		143.3	95	13614
Passenger 1		242.51	95	23038
Passenger 2		130.07	132	17169
Passenger 3		138.69	132	18307
Passenger 4		110.23	163.5	18023
Passenger 5		138.69	163.5	22676
Passenger 6		143.3	195	27944
Passenger 7		143.3	195	27944
Passenger 8		0	229	0
Passenger 9		0	247	0
Baggage nose		176	19	3344
Baggage rear		0	192	0
Standard cooler box		22	255	5610
Other				0
Other				0
TOTAL WEIGHT AND MOMENT		**7001.7**		**876943**

Passenger seating

Front of Aircraft

Pilot = 65 kg = 143.3 lbs	CS = 110 kg = 242.51 lbs.
ABE = 59 kg = 130.07 lbs	ABU = 62 kg = 138.69 lbs
TD = 50 kg = 110.23 lbs	UR = 62 kg = 138.69 lbs
RM = 65 kg = 143.3 lbs	MS = 65 kg = 143.3 lbs

Rear of aircraft

C of G position **125.2**

MASS AND BALANCE CALCULATIONS

ZS-OJY on 01/11/99	Quantity [U.S Gall.]	Weight [lbs.]	Arm [in.]	Moment [lb. Ins.]
Empty Weight		4594.4	124.1	570071.9
Fuel (Inboard)	106	636	126.8	80644.8
Fuel (Outboard)	76	456	148	67488
Fuel (Nacelle)	54	324	142.8	46267.2
Pilot 2		171.96	95	16336.2
Passenger 1		242.51	95	23038.45
Passenger 2		130.07	132	17169.24
Passenger 3		138.69	132	18307.08
Passenger 4		110.23	163.5	18022.61
Passenger 5		138.69	163.5	22675.82
Passenger 6		165.35	195	32243.25
Passenger 7		110.23	195	21494.85
Passenger 8		143.3	229	32815.7
Passenger 9		143.3	247	35395.1
Baggage nose		220	19	4180
Baggage rear		0	192	0
Standard cooler box		22	255	5610
Other				0
Other				0
TOTAL WEIGHT AND MOMENT		7746.7		1011760
C of G position			130.6	

Passenger seating

Front of Aircraft

Pilot = 65 kg = 143.3 lbs	CS = 110 kg = 242.51 lbs.
ABE = 59 kg = 130.07 lbs	ABU = 62 kg = 138.69 lbs
TD = 50 kg = 110.23 lbs	UR = 62 kg = 138.69 lbs
FS = 75 kg = 165.35 lbs	NG = 50 kg = 110.23 lbs
RM = 65 kg = 143.3 lbs	MS = 65 kg = 143.3 lbs

Rear of aircraft

MASS AND BALANCE CALCULATIONS

ZS-OJY on 08/11/99	Quantity [U.S Gall.]	Weight [lbs.]	Arm [in.]	Moment [lb. Ins.]
Empty Weight		4594.4	124.1	570071.91
Fuel (Inboard)	106	636	126.8	80644.8
Fuel (Outboard)	76	456	148	67488
Fuel (Nacelle)	54	324	142.8	46267.2
Pilot 1		143.3	95	13613.5
Passenger 1		242.51	95	23038.45
Passenger 2		130.07	132	17169.24
Passenger 3		138.69	132	18307.08
Passenger 4		110.23	163.5	18022.605
Passenger 5		138.69	163.5	22675.815
Passenger 6		143.3	195	27943.5
Passenger 7		143.3	195	27943.5
Passenger 8		0	229	0
Passenger 9		0	247	0
Baggage nose		176	19	3344
Baggage rear		0	192	0
Standard cooler box		22	255	5610
Other				0
Other				0
TOTAL WEIGHT AND MOMENT		7398.5		942139.6
C of G position			127.3	

Passenger seating

Front of Aircraft

Pilot = 65 kg = 143.3 lbs	CS = 110 kg = 242.51 lbs.
ABE = 59 kg = 130.07 lbs	ABU = 62 kg = 138.69 lbs
TD = 50 kg = 110.23 lbs	UR = 62 kg = 138.69 lbs
RM = 65 kg = 143.3 lbs	MS = 65 kg = 143.3 lbs

Rear of aircraft

MASS AND BALANCE CALCULATIONS

ZS-JJB on 15/11/99	Quantity [U.S Gall.]	Weight [lbs.]	Arm [in.]	Moment [lb. Ins.]
Empty Weight (incl. full oil)		4521.6	122	551142.7
Fuel (Inboard)	106	636	127	80644.8
Fuel (Outboard)	76	456	148	67488
Fuel (Nacelle)		0		0
Pilot 1		143.3	95	13613.5
Passenger 1		242.51	95	23038.45
Passenger 2		130.07	132	17169.24
Passenger 3		132.28	132	17460.96
Passenger 4		110.23	164	18022.61
Passenger 5		138.69	164	22675.82
Passenger 6		165.35	195	32243.25
Passenger 7		110.23	195	21494.85
Passenger 8		143.3	229	32815.7
Passenger 9		143.3	247	35395.1
Baggage nose		220	19	4180
Baggage rear			192	0
Standard cooler box		22	255	5610
Other				0
Other				0
TOTAL WEIGHT AND MOMENT		7314.9		942995
C of G position			129	

Passenger Seating

Front of Aircraft

Pilot = 65 kg = 143.3 lbs	CS = 110 kg = 242.51 lbs.
ABE = 59 kg = 130.07 lbs	LM = 60 kg = 132.28 lbs
TD = 50 kg = 110.23 lbs	UR = 62 kg = 138.69 lbs
FS = 75 kg = 165.35 lbs	NG = 50 kg = 110.23 lbs
RM = 65 kg = 143.3 lbs	MS = 65 kg = 143.3 lbs

Rear of aircraft

MASS AND BALANCE CALCULATIONS

	Quantity	Weight	Arm	Moment

Passenger seating

Front of Aircraft

ZS-OJY on 22/11/99	[U.S Gall.]	[lbs.]	[in.]	[lb. Ins.]
Empty Weight		4594.4	124.08	570071.9
Fuel (Inboard)	106	636	126.8	80644.8
Fuel (Outboard)	76	456	148	67488
Fuel (Nacelle)	54	324	142.8	46267.2
Pilot 2		171.96	95	16336.2
Passenger 1		242.51	95	23038.45
Passenger 2		130.07	132	17169.24
Passenger 3		138.69	132	18307.08
Passenger 4		110.23	163.5	18022.61
Passenger 5		138.69	163.5	22675.82
Passenger 6		143.3	195	27943.5
Passenger 7		143.3	195	27943.5
Passenger 8		0	229	0
Passenger 9		0	247	0
Baggage nose		176	19	3344
Baggage rear		0	192	0
Standard cooler box		22	255	5610
Other				0
Other				0
TOTAL WEIGHT AND MOMENT		**7427.1**		**944862.3**
C of G position			**127.22**	

Pilot = 65 kg = 143.3 lbs | CS = 110 kg = 242.51 lbs.

ABE = 59 kg = 130.07 lbs | ABU = 62 kg = 138.69 lbs

TD = 50 kg = 110.23 lbs | UR = 62 kg = 138.69 lbs

RM = 65 kg = 143.3 lbs | MS = 65 kg = 143.3 lbs

Rear of aircraft

MASS AND BALANCE CALCULATIONS

ZS-OJY on 01/11/99	Quantity [U.S Gall.]	Weight [lbs.]	Arm [in.]	Moment [lb. Ins.]
Empty Weight		4594	124	570071.9
Fuel (Inboard)	106	636	127	80644.8
Fuel (Outboard)	76	456	148	67488
Fuel (Nacelle)	54	324	143	46267.2

Passenger seating

Front of Aircraft

Pilot = 65 kg = 143.3 lbs | FS = 75 kg = 165.35 lbs

ABE = 59 kg = 130.07 lbs | NG = 50 kg = 110.23 lbs

TD = 50 kg = 110.23 lbs | UR = 62 kg = 138.69 lbs

HG = 54 kg =119.05 lbs

Pilot 1	143.3	95	13613.5
Passenger 1	165.4	95	15708.25
Passenger 2	130.1	132	17169.24
Passenger 3	110.2	132	14550.36
Passenger 4	110.2	164	18022.61
Passenger 5	138.7	164	22675.82
Passenger 6	119.1	195	23214.75
Passenger 7	143.3	195	27943.5
Passenger 8	143.3	229	32815.7
Passenger 9	0	247	0
Baggage nose	198	19	3762
Baggage rear	0	192	0
Standard cooler box	22	255	5610
Other			0
Other			0
TOTAL WEIGHT AND MOMENT	7434		959557.6
C of G position		129	

RM = 65 kg = 143.3 lbs   MS = 65 kg = 143.3 lbs

Rear of aircraft

MASS AND BALANCE CALCULATIONS

ZS-OJY on 06/12/99	Quantity [U.S Gall.]	Weight [lbs.]	Arm [in.]	Moment [lb. Ins.]
Empty Weight		4594.39	124.08	570071.91
Fuel (Inboard)	106	636	126.8	80644.8
Fuel (Outboard)	76	456	148	67488
Fuel (Nacelle)	54	324	142.8	46267.2
Pilot 2		171.96	95	16336.2
Passenger 1		242.51	95	23038.45
Passenger 2		130.07	132	17169.24
Passenger 3		138.69	132	18307.08
Passenger 4		110.23	163.5	18022.605

Passenger seating

Front of Aircraft

Pilot = 78 kg = 171.96 lbs	CS = 110 kg = 242.51 lbs.
ABE = 59 kg = 130.07 lbs	ABU = 62 kg = 138.69 lbs
TD = 50 kg = 110.23 lbs	UR = 62 kg = 138.69 lbs
HG = 54 kg = 119.05 lbs	NG = 50 kg = 110.23 lbs
RM = 65 kg = 143.3 lbs	MS = 65 kg = 143.3 lbs

Rear of aircraft

Passenger 5	138.69	163.5	22675.815
Passenger 6	119.05	195	23214.75
Passenger 7	110.23	195	21494.85
Passenger 8	143.3	229	32815.7
Passenger 9	143.3	247	35395.1
Baggage nose	226.61	19	4305.59
Baggage rear	83.69	192	16068.48
Standard cooler box	22	255	5610
Other			0
Other			0
TOTAL WEIGHT AND MOMENT	7790.72		1018925.8
C of G position		130.787	

5.4 **Appendix D**

5.4.1 REASON MODEL

A leading theorist in the systemic analysis of "organisational accidents" is Professor James Reason, of the University of Manchester, UK. Reason defines organisational accidents as situations in which *latent conditions* (arising mainly from management decisions, workplace practices, or cultural influences[2]) combine adversely with "local triggering events" (Task/Environmental conditions, ie., weather, location, workplace conditions, equipment failures, etc.) and with *active failures* (errors and/or procedural violations) committed by individuals or teams at the "sharp end" of the organisation, to produce the accident (Reason, 1991).

Reason has developed an analytical model which can be used to identify safety deficiencies within organisations. The model can be applied both proactively, by operational managers, and reactively, by accident investigators. A graphical representation of the model appears in Figure 1 below.

Figure 1
The Reason Model

As can be seen from Figure 1, *latent conditions* may include:

- Organisational and system factors, including decisions or actions taken by senior management, regulators, industrial bodies,;

- Task and environmental conditions, such as:

  - deficiencies in line management of people and/or resources; and/or
  - "psychological precursors" of unsafe acts, such as employee attitudes and practices; influence of work-group cultures or sub-cultures; effects resulting from the management of change within an organisation; effects of poorly designed work plans, rosters, etc.

Reason also applies the medical metaphor of "resident pathogens" to describe latent conditions. Such conditions are usually initiated at a time and place remote from the accident site, and frequently lie dormant within a system for considerable time, until activated by active failures and/or local triggering events.

Active failures are "unsafe acts" which usually involve errors (often "honest mistakes") or violations made by workers at the front line of the work place. These factors, which can involve individual or team actions, typically combine with environmental or other local triggering events to find or breach a hole in the *defences* which have been established by organisations in an attempt to avoid safety occurrences.[3]

To illustrate how the model may be applied reactively to the investigation of a safety occurrence, consider the following simple hypothetical example of a fire-fighting accident:

> *We are called to investigate a domestic house fire. The fire appears to have been started by a man smoking in bed. The house did not have smoke alarms fitted and the man and his family perished in the fire. One fireman suffered smoke inhalation injuries at the scene. The house was destroyed. There is some concern that the fire brigade took too long to respond to the fire and that a faster response may have saved lives and prevented total destruction of the house. The brigade has been subject to budget and staffing cuts in recent years and took longer than expected to respond as they were attending another fire.*

Active Failures: Man smoking in bed;
Fireman not wearing protective breathing apparatus.

Latent Conditions: No smoke alarms fitted (fallible decision by householder);
Budget cuts by government, leading to staff shortages, leading to longer response times (Organizational factor: fallible decision);
Budget cuts also led to reduced training for brigade members, which may have contributed to the injury (fallible decision by government/management);
However, this may also have been due to an attitudinal problem amongst some members regarding wearing of PBA (task environment condition/psychological precursor/line management deficiency);

This is not a definitive analysis of the above scenario. Rather, it is intended to illustrate how a tool like the Reason Model may be applied to analysis of safety occurrences after the event. We can see how latent conditions lie in wait to be triggered by active failures or other events. We can also see that without active failures, latent conditions may never fulfil their malevolent potential. Following such an analysis, recommendations would be issued to address the deficiencies noted.

The Reason Model has been adopted by the International Civil Aviation Organization (ICAO) as a recommended tool for the investigation of aircraft incidents and accidents (International Civil Aviation Organization, 1993, 1994). It is widely used by many safety investigation agencies, with Australia's Bureau of Air Safety Investigation (BASI)[4] leading the way in this regard. Reason's work has also been employed within a variety of potentially hazardous industries (including nuclear power, petrochemical, rail, shipping, medicine) with the goal of identifying safety deficiencies before they cause accidents and improving organisational safety performance.

Compiled by :

Date : 22 May 2001

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[1] The BHP Incident Cause Analysis Method (ICAM; BHP Corporate Safety, 2000) has also been employed as a framework to assist with this analysis.

[2] Can be derived from national, organisational and/or professional cultures.

[3] For a more comprehensive account of Reason's work, see his substantial publications on this subject (eg., Reason, 1990, 1991, 1997; also Maurino, Reason, Johnston & Lee, 1995).

[4] BASI is now part of the Australian Transport Safety Bureau ~ ATSB.