



Australian Government

Australian Transport Safety Bureau

**Boeing 747-438, VH-OJU
Sydney Aerodrome, NSW
2 July 2003**

**INVESTIGATION REPORT
BO/200302980**

CONTENTS

INTRODUCTION	iii
EXECUTIVE SUMMARY	iv
1. FACTUAL INFORMATION	1
1.1. History of the flight	1
1.2. Injuries to persons.....	4
1.3. Aircraft damage	4
1.4. Other damage.....	7
1.5. Personnel information	7
1.5.1 Pilot in command	7
1.5.2 Copilot.....	8
1.5.3 Second officer	8
1.5.4 Second officer pilot under initial training (PUIT)	8
1.6. Aircraft information.....	9
1.6.1 General information	9
1.6.2 Aircraft braking system.....	9
1.6.3 Escape slides	9
1.7. Meteorological information.....	9
1.8. Aids to navigation.....	10
1.9. Communications.....	10
1.10. Aerodrome information	10
1.11. Flight recorders.....	10
1.12. Wreckage information	10
1.13. Medical information	11
1.14. Fire.....	11
1.15. Survival aspects	11
1.16. Tests and research.....	14
1.17. Organisational information.....	15
1.17.1 Emergency procedures.....	15
1.18. Additional information	18
1.19. New investigation techniques	18
2. ANALYSIS	19
2.1. Introduction	19
2.2. Brake fire	19
2.2.1 Aircraft landing and taxi	19
2.2.2 Brake unit heat generation	19
2.2.3 Incorrect and excessive grease.....	20
2.2.4 Fire initiation.....	20
2.3. Aircraft evacuation	21
2.3.1 Evacuation announcement	21
2.3.2 Cabin crew action	21
2.3.3 Flight crew action	22
2.3.4 R3 door slide deflation.....	22
2.3.5 Use of over-wing slides	22
3. CONCLUSIONS	23
3.1. Findings	23
3.2. Significant factors.....	24
4. SAFETY ACTION.....	26
APPENDIX.....	28

INTRODUCTION

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

The ATSB is responsible for investigating accidents and other safety occurrences involving civil aircraft operations in Australia, as well as participating in overseas investigations involving Australian registered aircraft. A primary concern is the safety of commercial air transport, with particular regard to fare-paying passenger operations. Accordingly, the ATSB also conducts investigations and studies of the aviation system to identify underlying factors and trends that have the potential to adversely affect safety. The ATSB performs its aviation functions in accordance with the provisions of the Transport Safety Investigation Act 2003. The object of an occurrence investigation is to determine the circumstances to prevent other similar events. The results of these determinations form the basis for safety action, including recommendations where necessary. As with equivalent overseas organisations, the ATSB has no power to implement its recommendations.

It is not the object of an investigation to determine blame or liability. However, it should be recognised that an investigation report must include factual material of sufficient weight to support the analysis and conclusions reached. That material will at times contain information reflecting on the performance of individuals and organisations, and how their actions may have contributed to the outcomes of the matter under investigation. At all times the ATSB endeavours to balance the use of material that could imply adverse comment, with the need to properly explain what happened, and why, in a fair and unbiased manner.

Central to ATSB's investigation of aviation occurrences is the early identification of safety deficiencies in the civil aviation environment. While the Bureau issues recommendations to regulatory authorities, industry, or other agencies in order to address safety deficiencies, its preference is for organisations to make safety enhancements during the course of an investigation. The Bureau is pleased to report positive safety action in its final reports rather than make formal recommendations. Recommendations may be issued in conjunction with ATSB reports or independently. A safety deficiency may lead to a number of similar recommendations, each issued to a different agency. The ATSB does not have the resources or role to carry out a full cost-benefit analysis of each recommendation. The cost of a recommendation must be balanced against its benefits to safety, and aviation safety involves the whole community. Such analysis is a matter for the body to which the recommendation is addressed (for example the Civil Aviation Safety Authority in consultation with the industry).

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

EXECUTIVE SUMMARY

On 2 July 2003, the Boeing 747-438 aircraft, registered VH-OJU, operating on a scheduled flight from Singapore, arrived at Sydney at 0511 Eastern Standard Time, during the airport's curfew period. There was a tailwind of around 12 knots when the aircraft landed. The pilot flying selected auto brake setting three and idle reverse thrust in accordance with the curfew requirement. However, during the landing roll the reverse thrust was inadvertently de-selected.

On arrival at the terminal, the pilot in command (PIC) observed a BRAKE TEMP advisory message and notified the ground engineers. At that point, a fire ignited on the right wing landing gear. The flight crew were advised and the PIC ordered an evacuation of the aircraft. On receiving the evacuation announcement, the cabin crew commenced the evacuation drill deploying the aircraft's escape slides. The upper deck left (UDL) door and doors 2 left (L2) and 4 right (R4) escape slides, did not deploy. During the evacuation, the over-wing slide at door right 3 (R3) deflated while in use. As a result of the evacuation, one flight crew member and three passengers were seriously injured. Some passengers evacuated down the slides with their cabin baggage.

During the accident, an additional two brake fires ignited on the right body landing gear, one of which was extinguished by the Aerodrome Rescue and Fire Fighting Service (ARFFS). A subsequent inspection found that the aircraft's landing gear contained an excessive amount of grease with the presence of inappropriate grease on all of the landing gear axles. The three brake units that had caught fire were found to be serviceable but in a worn condition.

The investigation determined that slide R3 did not have any pre-existing defects that contributed to its failure. The nature of the failure was found to be overload of the fabric fibres during the evacuation. The inappropriate grease found on the landing gear axles was general purpose grease used on other components of the landing gear. The time and point of its application to the aircraft axles could not be determined.

The investigation found deficiencies in the operator's maintenance, flight crew and cabin crew procedures. As a result, the operator has issued maintenance memos to its engineering staff clarifying aircraft landing gear lubrication procedures, amended its Aircrew Emergency Procedures Manual, and reviewed cabin crew and flight crew emergency procedures.

As a result of this investigation, the ATSB is issuing safety recommendations to the operator and the Civil Aviation Safety Authority concerning the use of over-wing slides during known brake fires.

1. FACTUAL INFORMATION

1.1. History of the flight

On 2 July 2003, a Boeing 747-438 aircraft, registered VH-OJU, with 350 passengers (including three infants), 14 cabin crew and four flight crew was being operated on a scheduled passenger flight from Singapore to Sydney. The flight crew included the pilot in command (PIC), the copilot, a second officer, and a second officer pilot under initial training (PUIT).

Due to the forecast weather for Sydney and the expected arrival time within the airport's curfew period, the crew requested additional fuel in Singapore to allow for possible holding at Sydney, or a diversion to Brisbane. That gave the aircraft an expected landing weight at Sydney of 270,700 kg, approximately 15,000 kg less than the maximum allowable landing weight. The copilot was the handling pilot for the flight.

At approximately 0508 Eastern Standard Time, in darkness, the flight crew commenced an instrument landing system (ILS) approach to runway 34 left (34L) at Sydney airport. After commencing the approach, the aircraft encountered a varying tailwind. The landing reference airspeed (V_{REF}) was 150 knots for the flap 30 configuration and the planned aircraft landing weight. During the approach, the Sydney tower controller advised the crew that the surface wind was 180 degrees magnetic at 14 knots, with a tailwind component of 13 knots.

The crew planned to exit the runway at taxiway Golf (G) to facilitate a minimal taxi distance to their allocated parking bay and had set the automatic wheel brakes to position three for the landing¹. The landing distance available to taxiway G was 2826 metres, which was more than adequate for the prevailing conditions with an automatic wheel brake setting of three being appropriate for the conditions.

At approximately 0511, the aircraft touched down approximately 430 m past the threshold on runway 34L at an airspeed of 164 knots with a tailwind of approximately 12 knots. The landing was normal and soon after touchdown the spoilers automatically deployed and the auto-brakes activated. The flight crew advised the control tower that the aircraft's flight management computer (FMC) had indicated a tailwind component of 18 knots down to approximately 100 ft on final approach, and 11 knots at touchdown².

Approximately 5 seconds after landing, at 150 knots indicated airspeed, the copilot selected the reverse thrust levers to the idle reverse position. The PIC reported that he verbally reminded the copilot to use no more than idle reverse while placing his hand over the copilot's hand to prevent movement of the thrust levers beyond the idle reverse

¹ The automatic braking system on Boeing 747-400 series aircraft allowed the crew to preselect a desired deceleration rate during the landing roll (there were six settings RTO, 1, 2, 3, 4 and MAX). Brake torque was automatically adjusted to achieve a programmed rate of deceleration depending on, among other factors, the amount of reverse thrust that the crew had selected. For example, at a given automatic brake setting, if reverse thrust was not used, higher brake torques would be required than if reverse thrust was used.

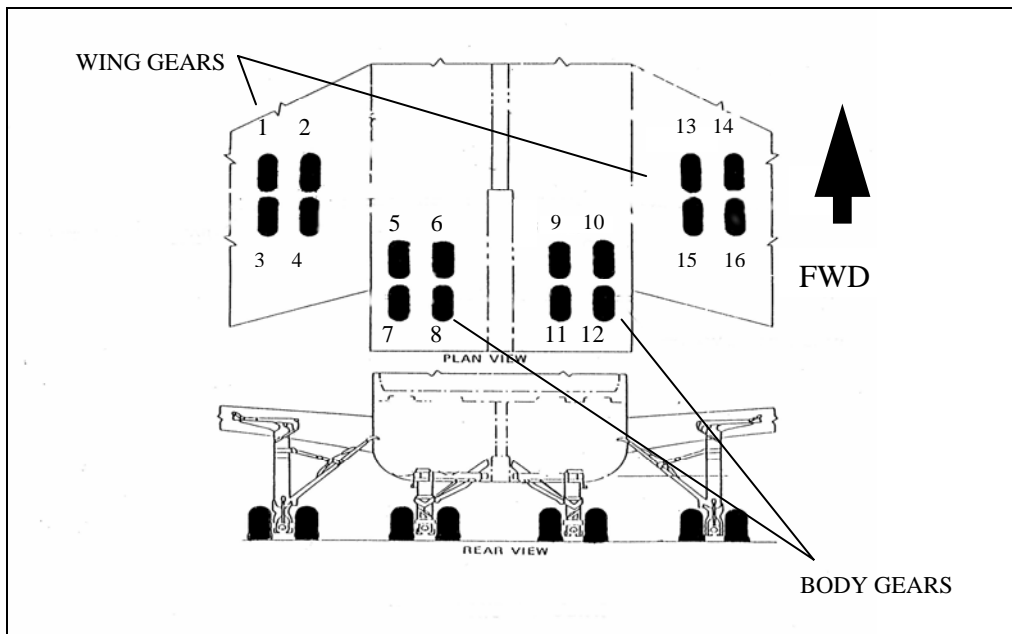
² Recorded flight data from the aircraft showed that the tailwind effect during the approach reduced from 16 knots at 200 ft, to 14 knots at 50 ft, and 12 knots at touchdown. The aircraft maintained a three degree glideslope until the flare manoeuvre prior to touchdown.

position. The PIC then removed his hand. Recorded flight data confirmed that the reverse thrust levers were raised to the idle reverse detent with the thrust reversers beginning to deploy normally. However, before any of the reversers reached the fully deployed position, and within two seconds of selection, the reverse thrust levers returned to the retracted position and the thrust reversers began to retract. The aircraft's speed at that time was 136 knots. None of the crewmembers reported noticing that the thrust reversers had deselected and the engines remained at forward idle thrust for the remainder of the landing roll.

As the aircraft decelerated through 100 knots, the PIC assessed that a higher rate of deceleration was required to allow exiting the runway at taxiway G. He directed the copilot to disarm the automatic wheel brakes and to apply manual braking. The copilot took those actions reducing the aircraft's speed to approximately 10 knots by the taxiway G turnoff.

When the aircraft was aligned with the designated parking bay, the flight crew instructed the cabin crew, via the passenger address system (PA), to disarm³ the cabin doors. The flight crew then observed a 'BRAKE TEMP' message on the primary Engine Indicating and Crew Alert System (EICAS) display screen on the flight deck instrument panel. The PIC checked the landing gear display page on the secondary EICAS screen and observed that the wheel brake temperature on wheel number-12 the rear right wheel on the right body landing gear (see Figure 1) was showing an amber five⁴ indication.

Figure 1: Main landing gear, wheel and brake configuration



As soon as the aircraft stopped, the ground crew commenced their aircraft arrival

³ The doors had two operating modes. Disarmed mode allowed the doors to be open without deployment of the escape slides. Armed mode automatically activated the escape slide on door opening.

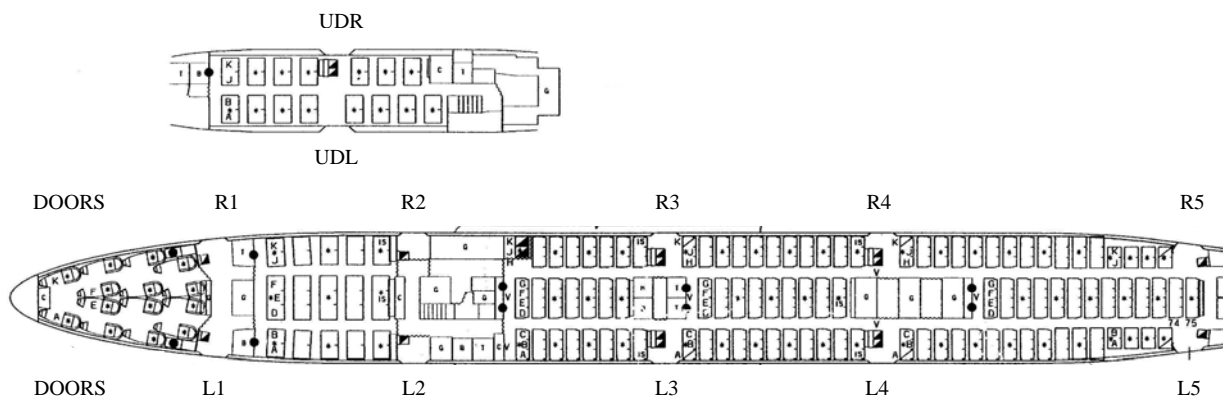
⁴ Brake temperature was displayed as numerically increasing levels (0 - 9) that were directly proportional to brake temperature. At level five (482° C.) the numeral changed colour from white to amber to indicate a transition to the high brake temperature range. Simultaneously an amber 'BRAKE TEMP' advisory message appeared on the primary EICAS display.

procedures. One of the ground engineers (GE1) connected his headset at the nose landing gear, for communication with the flight crew, and advised them that the wheel chocks were in place. The aircraft's flashing beacon was turned off and the copilot advised the ground engineer of the aircraft's status, including the hot brakes information. In the meantime, the cabin crew had disarmed the doors, and some passengers were standing holding their cabin baggage in readiness to disembark, even though the seatbelt sign was still illuminated. There was a slight delay before the seatbelt sign was extinguished, because the PIC had been dealing with the 'BRAKE TEMP' message.

On the ground, the second ground engineer (GE2) and a number of ramp personnel positioned on the right side of the aircraft noticed a fire in the right wing landing gear. GE2 immediately told GE1 of the fire, who then advised the flight crew. The PIC asked GE1 to confirm that there was a fire, and GE1 confirmed this. Communication between the flight crew and GE1 then ceased. The aircraft's flashing beacon was then turned back on, to signal ramp personnel to remain clear of the aircraft.

The PIC then made an 'Alert' PA to the aircraft cabin instructing all passengers to pay attention, to remain seated and await further instructions. The customer service manager (CSM) reported that by that time he had moved from his primary position at door 2 left (L2) and was supervising normal disembarkation through door 1 left (L1) to the aerobridge. All aircraft cabin doors except door L1 remained closed and disarmed. A small number of passengers had already left the aircraft (see Figure 2).

Figure 2: Aircraft cabin configuration & door locations



Within seconds of making the 'Alert' announcement, the PIC gave the order 'Evacuate, Evacuate, Evacuate' and activated the Emergency Evacuation Signal System, causing the main cabin lighting to extinguish and the cabin emergency lighting to illuminate. It was still dark outside, but the aircraft and surrounding area were illuminated by tarmac floodlighting. The cabin crew commenced evacuation procedures immediately with the first passenger escape slide, recorded on the airport security camera video, deploying at 0519:09.

1.2 Injuries to persons

Injuries	Crew	Passengers	Others	Total
Fatal	0	0	0	0
Serious	1	3	0	4
Minor	1	4	0	5
None	16	343	0	359
TOTAL	18	350	0	368

Of the 368 passengers and crew on board the aircraft, one flight crew member and three passengers were seriously injured. The most serious being to the passenger seated on the right (R3) over-wing slide at the time it deflated. Landing heavily on the tarmac she received a fractured vertebra that required surgery. One passenger sustained a fracture to her arm and another fractured her foot. Both were as a result of using the escape slides. The copilot, on descending the upper deck right (UDR) slide, holding a 3 kg BCF fire extinguisher, found that he was unable to control his speed and stability. During his descent he released the fire extinguisher, but momentum propelled him forward, subsequently landing heavily on his shoulder, fracturing his collar bone. A further four passengers and one cabin crewmember were treated for minor injuries.

Of the remaining passengers, a number reported injuries in the form of cuts, abrasions, sprains and bruising. One of those was a male passenger who descended down the L3 over-wing slide holding an infant. That passenger reported that his wife evacuated first with the intention of being able to assist him when he followed with the infant. However, she fell at the base of the slide and cut her right elbow. He evacuated, holding the infant on his right hip with his right arm. He believes he tried to slow down using his left arm, but it was a fast descent. He also fell off the end of the slide, tearing his clothes and cutting his left knee and hand. The infant was unharmed.

1.3 Aircraft damage

1.3.1 Landing gear

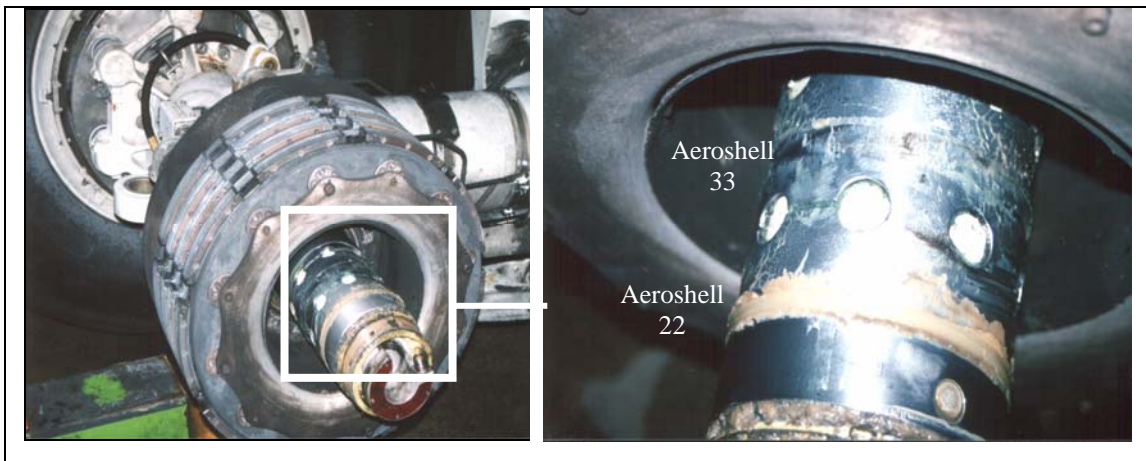
The right body and wing landing gears were examined. Other than sooting evident, the landing gear bogies had not sustained any damage as a result of the fires. The number- 9 and 13 wheels and brake units showed evidence of fire and the presence of pelletised grease. These components were removed and sent to an overhaul facility for disassembly and further examination. The number- 12 wheel showed signs of a possible flash fire. That wheel was inspected with no damage found.

An examination of the axles after wheels 9 and 13 were removed revealed the presence of the correct Aeroshell 22⁵ grease and a green-blue grease later identified as Aeroshell 33. Although not recommended for use in the high temperature axle area as it had a lower flashpoint⁶ than the approved Aeroshell 22 grease, Aeroshell 33 was an approved lubricant for other areas of the landing gear. The Aeroshell 33 grease was most predominant on the inboard area of the axle, with the correct Aeroshell 22 grease visible toward the axle's outer region (see Figure 3).

⁵ Aeroshell 22 - amber coloured synthetic hydrocarbon grease.

⁶ Flash point: Temperature at which the grease vapours will ignite.

Figure 3: Incorrect grease on axle



After the discovery of the two contaminated axles, the operator inspected the remaining axles and found they also contained Aeroshell 33 grease. It was also noted that an excessive amount of grease was present on the axles and in the brake unit cavities. The lubrication of the landing gear axles and brake unit interface was required whenever the wheels or brakes were replaced. Brake units were also lubricated during the more detailed landing gear lubrication procedures.

The aircraft manufacturer's maintenance procedures for wheel and brake removal/installation carried the following warning and caution:

AMM 747-438/48E/4H6, task 32-41-15-404-014, subtask 32-41-15-644-047
Landing gear – hydraulic brake system - brake unit – landing gear –
removal/installation.

Warning

Apply a thin layer of grease to the interface surfaces of the brake and axle only. Do not apply grease in the space between the axle bushings on the brake assembly. If you apply too much grease, a fire can occur when the brake becomes hot.

and:

AMM 747-438/48E/4H6, task 32-45-01-404-019, subtask 32-45-01-424-071
Landing gear – tires and wheels – assembly - Main landing gear tire/wheel
removal/installation.

Caution

Do not apply grease to the area between the axle bearings. The high temperatures in this area during a landing can cause all grease in the area to burn. This can cause damage to the wheels, tires and brakes.

The procedures then directed the removal of any unwanted grease with a rag. Landing gear lubrication and wheel/brake changes were carried out at a number of locations, including both the operator's and external maintenance facilities.

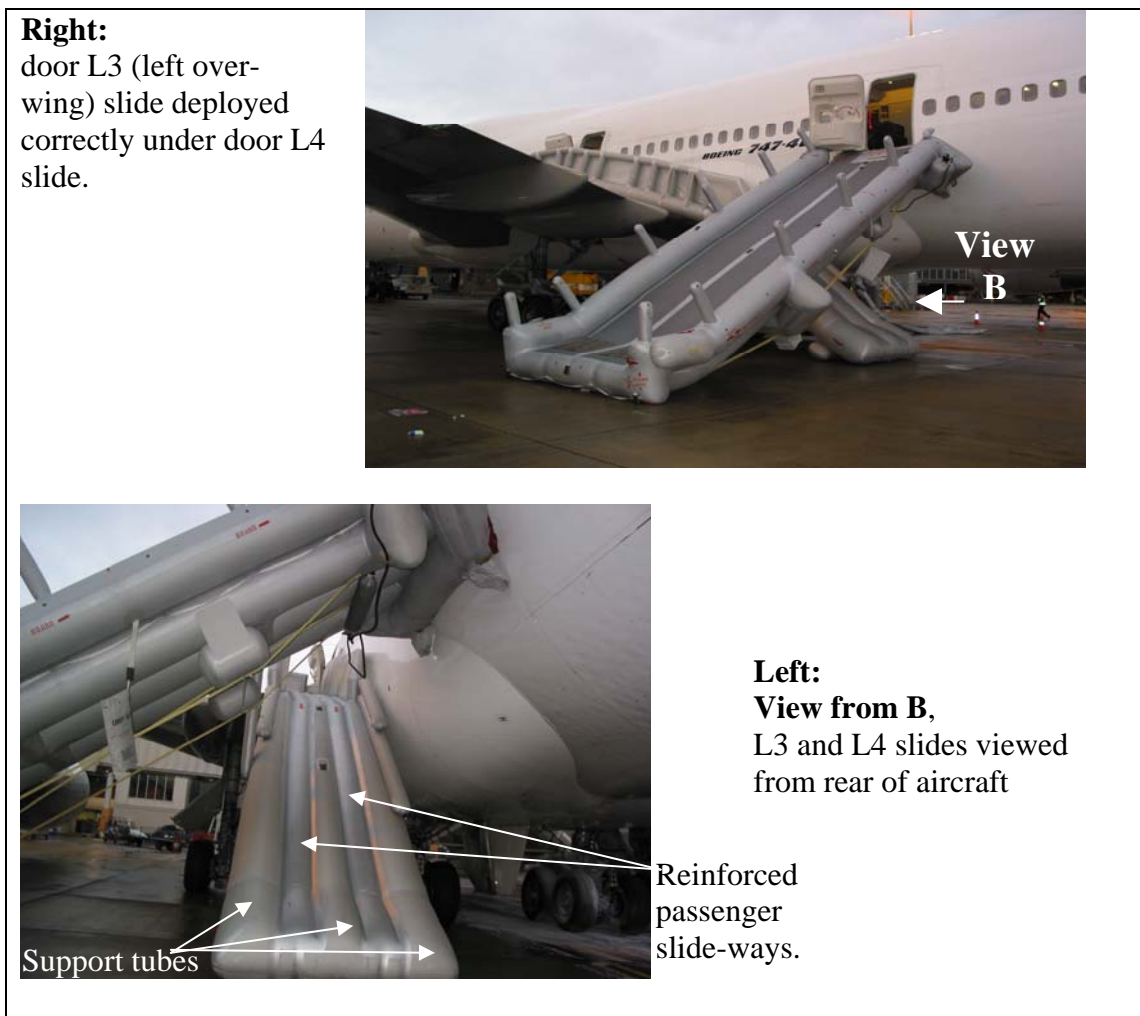
A review of the aircraft's maintenance records showed that the number- 9 and 13 wheels had been fitted to the aircraft in June 2003 and May 2003 respectively, with brake units

fitted on November 2000 and March 2000 respectively. The aircraft had not undergone recent maintenance that required lubrication of the axles of the affected wheels.

1.3.2 Over-wing slides

Doors L3 and R3 were over-wing doors, their evacuation slides inflated to form a corridor directing passengers rearward over the wing to its trailing edge, then continuing as a slide to the ground. The slides were air inflated, self-supporting structures, which comprised two inflated reinforced slide-ways separated by an inflated central tube and bounded by outer inflated support tubes (see Figure. 4).

Figure 4: Left over wing slide deployment



Initial inspection of the right over-wing (R3) slide, indicated a longitudinal tear of approximately 1.5 metres down its centre tube (see Figure 5). The slide was removed from the aircraft and sent to the Australian Transport Safety Bureau (ATSB) for technical examination.

The examination revealed that the longitudinal tear was 154 cm long. There was a small transverse tear, extending 2.8 cm from the longitudinal tear toward the right slide-way reinforcement, 71 cm from the longitudinal tear's upper end.

Visual inspection of the slide material did not reveal any indication of fabric fibre or fabric proofing deterioration. A microscopic examination of the tear features determined

that both tears followed the weave of the fabric, with tearing occurring due to a tensile fracture of the fibres.

A small section from the region immediately surrounding the transverse tear was cut from the slide to allow for light and scanning electron microscopic examination. This examination showed an abrasion of the raised portion of weave on the upper side of the tear corner, indicating that sliding contact between the slide and another object occurred under high contact pressure over a short distance. No evidence of fibre cutting or sharp object penetration was observed. A detailed report of the slide failure is contained in appendix A.

Figure 5: Door R3 slide deflated



1.4 Other damage

No other damage was reported.

1.5 Personnel information

1.5.1 Pilot in command

Type of licence	ATPL
Medical certificate	Class 1
Flying experience (total hours)	15,133
Hours on the type	2,400
Hours flown in the last 24 hours	7
Hours flown in the last 30 days	77
Hours flown in the last 90 days	141

1.5.2 Copilot

Type of licence	ATPL
Medical certificate	Class 1
Flying experience (total hours)	19,500
Hours on the type	300
Hours flown in the last 24 hours	7
Hours flown in the last 30 days	30
Hours flown in the last 90 days	150

Both the pilot in command and the copilot had extensive flying experience, holding valid endorsements on the aircraft type. The copilot was the handling pilot for the aircraft's arrival and landing sequence. The PIC then took control of the aircraft as it approached the terminal as per the operator's procedures, becoming the handling pilot at the time of the accident⁷. The recent work history of the crew did not identify any fatigue issues that may have affected their performance.

1.5.3 Second officer

Type of licence	ATPL
Medical certificate	Class 1
Flying experience (total hours)	4,953
Hours on the type	781
Hours flown in the last 24 hours	7
Hours flown in the last 30 days	64
Hours flown in the last 90 days	210

1.5.4 Second officer pilot under initial training (PUIT)

Type of licence	ATPL
Medical certificate	Class 1
Flying experience (total hours)	5,950
Hours on the type	38
Hours flown in the last 24 hours	7
Hours flown in the last 30 days	38
Hours flown in the last 90 days	38

The PUIT had been in the right seat during the en-route phase of the flight, but was replaced by the copilot for the approach and landing at Sydney.

⁷ Accident: an investigable matter involving a transport vehicle where a person dies or suffers serious injury as a result of an occurrence associated with the operation of the vehicle – Transport Safety Investigation Act 2003 Part 1 Section 3. Serious Injury: an injury that requires or would usually require, admission to hospital within 7 days after the day when the injury is suffered.

1.6 Aircraft information

Manufacturer	Boeing
Model	747-438
Serial number	25566
Registration	VH-OJU
Year of manufacture	1999
Weight at occurrence	270,700kg

1.6.1 General information

The aircraft was approximately 4 years old and had been in service with the current operator from manufacture. At the time of the accident, the aircraft was serviceable with all required maintenance and airworthiness documentation completed.

1.6.2 Aircraft braking system

The aircraft brakes were self adjusting, hydraulically actuated, multiple disc units, each containing four rotor and three stator discs made of carbon. Brake wear was measured by the use of two indicator pins fitted to the units. During assembly, the pins were set to a predetermined protrusion length with hydraulic pressure applied (brakes on). As the stator and rotor discs wore, the indicator pin protrusion decreased. At a designated 'brakes on' protrusion length, it was determined that the stator and rotor discs had worn to their serviceable limits requiring the brake unit to be replaced and overhauled.

Friction energy created during the braking process creates heat. That heat is then dissipated through the stators and rotor of the brake unit and into the atmosphere. The amount of energy required to stop an aircraft was the same for a new brake unit as a worn unit, however, the total mass of the stators and rotors on a worn brake unit was reduced. Because of this, worn brakes could reach a higher peak temperature quicker than a new brake unit when subjected to the same friction forces. The dissipation of heat was also quicker for worn brakes.

1.6.3 Escape slides

All of the aircraft door escape slides were correctly fitted to the aircraft and in serviceable condition. The mode selectors on all doors were examined and found to be working normally.

1.7 Meteorological information

The wind velocity during the approach was recorded by the aircraft's quick access recorder (QAR). The QAR data indicated that the wind velocity changed during the approach, which resulted in a varying tailwind component (TWC). At 2,000 ft, as the flight crew commenced the final approach, the TWC was approximately 16 knots. At 1,500 ft the TWC was approximately 17 knots. From 1,000 ft to 200 ft the TWC was approximately 22 knots, reducing to 12 knots on touchdown.

1.8 Aids to navigation

Runway 34L at Sydney, was equipped with an ILS that provided precise guidance to aircraft during the landing approach. The ILS localiser beam provided guidance in the horizontal plane along the extended centreline of the runway. The ILS glideslope beam provided guidance in the vertical plane of three degrees to the touchdown point. There were no reported anomalies with the ILS at the time of the occurrence.

1.9 Communications

All communications between ATIS and the crew were recorded by ground based automatic voice recording equipment for the duration of the flight. The quality of the recorded transmissions was good.

The aircraft was equipped with three very high frequency (VHF) radio communication systems. The flight crew used two of the VHF radios for routine communications with air traffic control, and the remaining set was used for the aircraft communications addressing and reporting system (ACARS) data link system. All VHF radios were serviceable.

1.10 Aerodrome information

Sydney airport had two parallel runways, runway 16 right/34 left and 16 left/34 right, and a cross runway, runway 07/25. The airport had in force a curfew that operated from 2300 to 0600 daily. Permitted aircraft movements during those hours were limited to a quota of BAe146 freight aircraft, noise certificated propeller aircraft under 34,000 kilograms, jet aircraft under 34,000kg which complied with the applicable noise standards and aircraft emergencies. During the curfew, only the main north-south runway (16R-34L) was used.

Limited international passenger jet arrivals were permitted between 0500 and 0600. Those aircraft were restricted by noise abatement requirements that included, no more than idle reverse thrust to be used during the landing roll and the use of runway 34L only.

1.11 Flight recorders

The aircraft was fitted with an L3 Communications FA2100 solid state digital flight data recorder. The recorded data was downloaded by the ATSB for analysis.

The aircraft was also equipped with a quick access recorder (QAR), which was downloaded by the operator and the data forwarded to the ATSB for analysis.

Recorded information contained on the solid state cockpit voice recorder (CVR) fitted to the aircraft had been overwritten and could not be utilised during the investigation.

1.12 Wreckage information

Not applicable

1.13 Medical information

There was no evidence that any psychological or medical factors affected the performance of the flight crew or cabin crew.

1.14 Fire

A brake fire was identified as being on the number-13 wheel, consisting of flames rising 20 cm above the top of the tyre and giving off a substantial amount of smoke.

At 0518.47, the copilot broadcast 'Mayday' on the Sydney Tower/Ground frequency advising that there was a brake fire on the right landing gear and requesting emergency services. The tower controller acknowledged the Mayday, advising that the crash alarm had been activated and that fire tenders would respond immediately.

The Aerodrome Rescue and Fire Fighting Service (ARFFS) arrived at the aircraft within 4 minutes of the activation of the crash alarm. On their arrival, there was no evidence of actual fire, however, a large amount of smoke was still present in the right landing gear area. The ARFFS positioned vehicles and crews to the rear of the right landing gears. It was apparent that the aircraft had already been evacuated with most of the escape slides being deployed. The majority of evacuated passengers had been ushered into the terminal building, with only three requiring first aid remaining in the vicinity of the aircraft.

While the ARFFS were in position, another fire ignited on the right body landing gear number-9 wheel, it was suppressed with chemical dry powder. Later, after a review of the tarmac surveillance video, it was revealed that a third wheel fire had occurred. That fire (a momentary flash fire that self extinguished) occurred during the evacuation and prior to the arrival of the ARFFS. That fire was believed to have occurred on the number-12 wheel.

1.15 Survival aspects

Aircraft evacuation

The aircraft cabin layout was divided into six zones. These were designated from the front of the aircraft to the rear as zones A through to E on the main deck and zone F for the upper deck. Each main deck zone was separated by the entry doors on the left and right sides of the aircraft (see Figure 2). The aircraft had a three class seating configuration (first, business and economy), but was being operated as a two class service with first class seating sold as business class at the time.

The evacuation was initiated while it was still dark, and after the seat belt sign had been turned off, and passengers had begun to retrieve their cabin baggage. Eight of the 12 escape slides fitted to the aircraft were deployed (see Figure 6). Door L1 slide was not used because the door was already opened to the aerobridge. Doors L2, R4 and upper deck left (UDL) were opened while they were still in the disarmed mode and consequently the slides on those doors did not inflate. In accordance with the operator's procedures, those exits were declared blocked by the cabin crew who then directed passengers to other doors.

The UDR escape slide was deployed, but it landed on a baggage handling vehicle

positioned at the forward cargo bay door. The cabin crewmember at that exit then declared it blocked. Ground crew quickly freed the slide from the vehicle and placed it in its normal position on the ground. The slide was not used for evacuation by the upper deck passengers who had descended to the main deck. However, the copilot evacuated by way of that slide.

Figure 6: Slide deployment



The cabin crew reported a number of difficulties in applying the evacuation procedures, particularly those regarding cabin luggage. Some were unsure as to whether the priority should be to get the passengers off the aircraft as quickly as possible and ignore cabin baggage, or to insist that all cabin baggage be left on the aircraft. Other cabin crew, who followed operator procedures and insisted that cabin baggage be left behind, reported a build-up of baggage in the aisles and around doorways, potentially slowing passenger movement from the aircraft.

The ground crew observed passengers colliding with each other at the base of the slides where they congregated, not knowing what to do next. The ground crew, acting on their own initiative, began assisting passengers as they came down the slides, providing them with blankets and directing them away from the aircraft to safety.

The brake fire had self extinguished by the time the evacuation procedures had commenced, although there was still a substantial amount of smoke present around the landing gear. Knowing that the fire had been extinguished, both of the ground engineers

moved to the base of slide R2 and, in an attempt to stop the evacuation, waved and called to the cabin crewmember attending that door. Although their gestures were seen, the cabin crewmember continued with the evacuation in accordance with the operator's training procedures, assisting a wheel chair passenger onto the R2 slide. The crewmember was about to descend down the slide with the passenger when the ground crew signalled her not to, indicating they would take care of the passenger. After the passenger had safely reached the base of the slide and had been aided by the ground crew, the cabin crewmember checked that all other passengers had left her area before disembarking onto the aerobridge.

On hearing the 'evacuate' PA, the cabin crewmember at door R3 (over-wing exit) looked through the window and saw fire trucks approaching the rear of the aircraft. She re-armed the door and opened it. On seeing the slide's off-wing deployment indicator (ODI) she began the evacuation. Although she could not see the area where the slide reached the ground she observed the ground crew assisting passengers. After a number of passengers had evacuated, the cabin crewmember noticed that the slide was deflating, and she declared R3 to be a 'blocked exit'. As noted previously, a passenger who was on the slide at the time it deflated was seriously injured.

After opening door L3, the cabin crewmember looked out and observed the ODI, but the drop of the slide appeared steeper than he had observed during training. Before issuing evacuation instructions, he asked a nearby male passenger to step onto the wing ramp (the section of slide over the wing surface) and check that the lower section of the slide had inflated. Once inflation had been confirmed, evacuation from L3 commenced.

Most of the passengers evacuated the aircraft through doors 4 left and 5 left and right. It was estimated that between, 70 to 80 passengers left the aircraft via the aerobridge door L1.

Immediately after the evacuation command was given, the second officer and the PUIT conducted the Landing Emergency Impact drills. Taking a torch each, they proceeded to the passenger cabin to assist with the evacuation. After confirming that all checklist items had been completed, the PIC and copilot proceeded to the upper deck cabin which was clear of passengers by that time. The PIC took his torch from the flight deck, but the copilot was unable to locate his torch⁸. In accordance with operator procedures, the copilot took the 3 kg BCF hand held fire extinguisher from the flight deck and evacuated through the right upper deck door. As he reached the bottom of the slide, the copilot fell and was injured.

By the time the PIC reached the main deck cabin, all passengers had left the aircraft and cabin crew had completed their area checks. The PIC went to door R2 to evacuate, but was waved away by the ground engineers. The PIC, the second officer, the PUIT and the cabin crew then exited through door L1 to the aerobridge. The PIC proceeded to the apron area to assist the passengers and noted that many of them had gathered near the parking bay immediately north of the aircraft. He returned to the aerobridge to summons assistance from the other crew members. However, by the time the group returned to the apron, all passengers had moved inside the terminal under the direction of the ground crew.

The airport security camera video indicated that all passengers had exited the aircraft

⁸ The copilot thought that there were no more torches available as the two torches on the toilet outer wall had been taken by the second officer and the pilot under initial training. The copilot was unaware that there was another torch available near the first observer's panel.

approximately 90 seconds after the first cabin door opened.

1.16 Tests and research

1.16.1 Wheel and brake inspection

Although wheels-9 and 13 showed evidence of sooting, they had not been subjected to sufficient heat to blister their surface coating or melt their fusible plugs⁹. However, there was a substantial amount of old grease and general debris on the inner rim of both wheels, which although not uncommon, was excessive. The bearings from both wheels were removed and inspected with no defects found. The bearings were found to be packed with the correct Aeroshell 22 grease.

Before being disassembled both brake units were purged to determine which grease was present within their bushing channels. They were then pressurised to check for hydraulic leaks and wear, using the wear pin indicators¹⁰ with the following results:

Number-9 brake unit

Purging of the brake bushing revealed dark discoloured grease that could not be easily identified. The pressure check of the brake unit confirmed there were no hydraulic leaks evident from any of the pistons and although the wear pin indicator was still within the serviceable range, the heat stack¹¹ was considerably worn with one of the rotor discs worn flush with its support clips. The brake heat shield was intact with no grease present. There was an excessive amount of grease found on the inner face of the brake unit. The brake unit 'O' ring seal was removed and found to be substantially deformed.

Number-13 brake unit

Purging of the brake bushing revealed a very small amount of green-blue grease identified as Aeroshell 33 within the brake unit. Pressurisation of the brake unit did not present any hydraulic leaks and again showed that although the brake unit was within serviceable limits on the wear pin indicator, the heat stack was considerably worn. There were minor grease smears on the heat shield, which was otherwise intact. The heat stack rotors and stators did not show any abnormal wear characteristics. The 'O' ring seal was removed and found to be complete, without any significant signs of deformation.

1.16.2 Other brake fire occurrences

In November 2000, one of the operator's Boeing 747-438 aircraft that had recently completed maintenance sustained a brake fire. On that occasion, the wheel interior and brake void were found to contain excessive amounts of grease, including Aeroshell 33. That incident resulted in the operator issuing a safety alert bulletin to the maintenance facility that had carried out the maintenance tasks, highlighting the incident and the importance of following correct maintenance procedures.

⁹ A safety device installed in the wheel hub designed to melt at a predetermined temperature.

¹⁰ Wear pin indicators show whether the brake unit heat stack is of a serviceable thickness.

¹¹ Heat stacks: term given to the stator and rotor discs that make up the brake unit.

On 3 July 2003, the day after the subject occurrence, another of the operator's Boeing 747-438 aircraft experienced a brake fire shortly after reaching the parking bay following a landing at Sydney. That aircraft also landed on runway 34L during the curfew period, with a tailwind component of 8 knots. The landing and deceleration were normal and idle reverse thrust was used. The fire occurred on wheel number- 11, which had a brake temperature indication of five. On that occasion, the fire self-extinguished before ground crew could apply an extinguisher. Examination of the landing gear revealed the presence of Aeroshell 33 grease and an excessive amount of grease around the wheel and brake unit. The brake unit was found to be worn and towards the end of its serviceable life.

After the incident on 3 July, the operator conducted a survey of its Boeing 747 fleet to examine the landing gear axles for signs of incorrect grease application and the presence of excessive amounts of grease. After examining 12 aircraft, the operator found two aircraft (the subject accident aircraft and the aircraft from 3 July) that had both incorrect type and excessive grease present. One other aircraft showed signs of excessive grease, with no other aircraft in its fleet displaying evidence of Aeroshell 33 grease on the axles.

As a result, the operator issued maintenance memo M0429-GEN-32-41-JUL 10/03, highlighting the precautions to be taken when lubricating wheel and brake assemblies. The memo also provided a warning in regard to the use of incorrect Aeroshell 33 grease on axles.

1.16.3 R3 slide failure

A copy of the technical report on the failure of the R3 slide is attached at appendix A.

1.17 Organisational information

1.17.1 Emergency procedures

Flight crew emergency procedures

The Boeing 747-400 quick reference handbook (QRH) contained information on non-normal situations or conditions. The Checklist Introduction - Non-normal Checklist CI 2.2 included the following statement: 'It should be stressed for persistent smoke or a fire that cannot be positively confirmed to be completely extinguished, the earliest possible descent, landing, and passenger evacuation should be accomplished.'

The Boeing 747-400 QRH did not contain any procedure that specifically addressed brake fires. The Boeing 747-200/300 QRH included a non-normal recall checklist titled: 'Brake or Wheel Fire (on Ground)'. The checklist stated: 'Request fire crew assistance, if fire is confirmed from either aircraft and/or external sources: carry out PASSENGER EVACUATION procedure.'¹²

¹² Because the materials used in the manufacture of wheels and brakes for the 747-400 aircraft were different from those used in the wheels and brakes on the earlier 747-200/300 models, the aircraft manufacturer had not included reference to brake or wheel fires in the 747-400 QRH.

Further relevant information for flight crews was contained in the operator's Flight Training Coordinated Briefing document titled: 'Land Emergencies'. Coordinated Briefing material provided additional information on items covered in the cyclic training program that all cabin and flight crew members underwent. The introduction to that publication stated that: 'The decision-making process to determine the correct course of action is a complex one, one that may require a rapid decision.' The introduction also stated: 'The presence of fire and/or smoke inside or outside the aircraft or the suspected presence of fire would indicate a necessity to evacuate the aircraft.'

Section 12.3 of the Aircrew Emergency Procedures Manual (AEPM) detailed the land evacuation impact drill for the copilot on the Boeing 747-400 aircraft. It stated that the copilot was to take a torch and BCF extinguisher from the flight deck, and to proceed to the upper deck and evacuate through the first available exit. The copilot was then required to check for fire and to extinguish if possible, and to check the escape slides and assist on ground the evacuation process.

The land evacuation impact drill for the PIC included the requirement 'to assemble the passengers away from the aircraft'. The second officer and supernumerary crew were required to, 'when all assistance in the cabin has been rendered, evacuate and assist on ground'.

Flight crew emergency procedures training

All company flight crew complete emergency procedures training twice each year, which includes training and testing of emergency procedures, and emergency equipment operation, as well as scenario based non-normal exercises. However, because of the limitations of the emergency procedures training mock-up and aircraft specific flight simulators, training exercises incorporating checklist recall and the various drills were difficult to conduct accurately.

The operator advised that because of the injury risk involved, and as it was not a requirement of the Civil Aviation Safety Authority, the upper deck escape slide training facility had not been used since 1999. Further, flight crew undertook escape slide training only during their initial training and not during type conversion or recurrent training. To provide guidance on the use of the slide a training video was shown at every emergency procedures training session. The copilot could not recall ever using the upper deck escape slide.

Cabin crew procedures

The cabin crew standard operating procedures provided information on the roles and responsibilities of door primary and assist crew members¹³. These included the closing, opening, arming and disarming of the doors. The 'AFTER LANDING' procedure specified that at close proximity to the terminal, the flight crew will make their 'Disarm Doors' announcement. The primary cabin crewmember at each door would then disarm that door and await a call from the CSM to confirm that the door had been disarmed.

The operators 'Onboard Manager Handbook 2-23' required the CSM to signal ground staff that it was safe to open the door, then hand over customs documentation and 'ships' satchel to the ground staff. When door L1 was used for disembarkation, the CSM was required to move from their assigned L2 door to accomplish these duties. The Aircrew

¹³ Cabin crew were allocated primary or assist functions at each cabin doors.

Emergency Procedures Manual (AEPM) did not assign an assist crew member at door L2 for this model aircraft.

Step 1 of the AEPM ‘Land Impact Drill Primaries – Expanded Information’, stated:

upon receipt of the evacuation Order or signal, Cabin Crew move to assigned door/exit, continually repeating the commands;

“Evacuate, Evacuate, Evacuate”

“Unfasten Seat Belts”

“High heels off”

Repeat these commands until doors/exits are available for use. Continue with directional/re-directional commands as applicable.

The procedure did not specify commands to leave cabin baggage behind. The on-board safety cards located in each seat depicted a bag with a circled cross through it next to a passenger evacuating, symbolising that bags were not to be taken during evacuations.

Cabin crew emergency procedures training

The cabin crew were required to complete a bi-annual Emergency Procedures (EP) training course, in which the Land Impact Drill [evacuation], as outlined in the AEPM was practiced. The operator’s records show that all of the cabin crew’s training requirements were current at the time of the accident.

The operator indicated that during the 2002 – 2003 bi-annual EP training, a land evacuation at the terminal was practiced. The scenario for the exercise was a wheel well fire warning after engine shut down procedures had been completed. During the exercise the doors were disarmed, so door rearming by cabin crew was required.

Ground crew procedures and training in the event of a evacuation at the gate

The actions taken by the ground crew during the accident were the result of individuals acting on their own initiative. The operator did not have in place procedures for ground crew actions during aircraft evacuations at airport terminals. There was no specific training program covering aircraft emergency procedures for ground crew nor was there a regulatory requirement for such training.

1.17.2 Operator’s Maintenance practices

The aircraft’s landing gears were lubricated to varying degrees during scheduled maintenance and at wheel and brake replacement. These procedures ranged from lubrication of selected points on the bogies (for example, after a brake/wheel change or post landing gear wash) to the entire landing gear lubrication procedure carried out during heavier scheduled maintenance. The operator followed the manufacturer’s lubrication procedures, which listed 4 different types of grease to be used on the landing gears.

Although the manufacturer’s procedures contained diagrams that clearly showed the locations to apply the appropriate lubricant, maintenance personnel worked from the

operators work sheets that give general details of components to lubricate, all materials to be used and a reference to the manufacturer's maintenance manual (for access to the lubrication diagrams), requiring personnel to independently obtain the relevant drawings. Both the aircraft manufacturer's and the operator's maintenance procedures included the instruction to wipe away any excess grease after lubrication had been carried out.

Landing gear lubrication was carried out at a number of approved maintenance facilities including third party organisations. Although all were accredited, variations in the local procedures for the handling of equipment existed. Some facilities held pneumatic grease guns in a central store that were issued on request. These guns connected directly to the top of large grease tins. Other locations issued hand held manual grease guns, which were filled from the larger tins, or used cartridges of grease. It was not uncommon for individual maintenance crews to hold their own grease guns on their work trolleys. Both Aeroshell 33 and Aeroshell 22 grease had been supplied to the operator in large tins that were identical in colour, however, after the accident, the operator changed procedures to ensure that Aeroshell 33 grease was obtained in clearly marked cartridges. Supply of Aeroshell 22 grease remained in the large tin form. The method of identifying equipment was a combination of colour coding and ID tag identifiers, but not all equipment in use was clearly marked.

1.18 Additional information

Flight crew duties

The Boeing 747-400 series aircraft's flight deck was designed for two pilot operations with seating provisions for an additional two personnel. The operations manual landing roll procedures specified that the flying pilot select reverse thrust. The procedures did not require the non-flying pilot to verify that selection.

The operator had incorporated in its Flight Administration Manual, duties for second officer crew members, which stated:

Second Officers

... .. Second Officers will draw the attention of other Flight Crew members to any particular factor that may have been overlooked by them.

... .. Second Officer duties will be allocated by the Pilot-In-Command or First Officer. The Second Officer, while not included in standard crew operating procedures, is expected to monitor and assist the operation in all respects.

The operator's Flying Manual contained a second officer line operations check list that stated, on the runway after landing, the second officer should ensure reverse thrust is selected.

1.19 New investigation techniques

No new investigation techniques were employed during this investigation.

2. ANALYSIS

2.1. Introduction

This occurrence comprised two main sequential events; brake fires, followed by the aircraft evacuation. To provide clear analysis, each event has been addressed separately.

2.2. Brake fire

2.2.1 Aircraft landing and taxi

Based on the information provided to the flight crew during the aircraft's approach, an appropriate configuration for landing was made with the aircraft flown well within its operational parameters. Although there appeared to be a varying tailwind component, the crew determined that it was within the landing limitations of the aircraft as detailed by the manufacturer. The tailwind and high landing weight of the aircraft did however result in a higher ground speed on touch down.

The crews intention was to use idle reverse thrust during the landing roll, in accordance with the airports curfew requirements. The action of the PIC placing his hand over the copilot's hand on the thrust lever, while drawing the copilot's attention to limiting the reverse thrust to idle only, may have resulted in the inadvertent deselection of the reversers. Subsequent additional braking force was then required from the auto brakes to maintain the desired aircraft deceleration rate. The flight crew's intention to exit the runway at taxiway Golf led to the application of additional manual braking to slow the aircraft to the required turn speed. Both of these actions added to the heat generated in the aircraft's brake units.

The use of runway 34L and taxiway Golf presented a relatively short taxi distance to the terminal after touchdown, thus reducing the heat dissipation time of the brakes before the aircraft stopped at its bay. This was evident by the 'BRAKE TEMP' message observed by the crew.

2.2.2 Brake unit heat generation

The amount of energy required by a brake unit to slow or stop an aircraft of a given weight, travelling at a given speed, within a given deceleration rate is the same for a new brake unit as for a worn one. However, the heat generated in dissipating that energy would be greater in a worn brake unit due to its reduced mass.

The brake units at wheels 9 and 13 had been on the aircraft for some time and although they were within their serviceable limits, their heat stacks showed significant wear. The brake manufacturer confirmed that worn heat stacks would generate a higher peak temperature in a shorter time frame than new heat stacks, but should also dissipate the heat quicker.

The brake unit from the second incident aircraft on 3 July 2003 also displayed significant wear in its heat stack.

In both circumstances, the highest brake temperature recorded was found to be within the operating range of the brake unit.

2.2.3 Incorrect and excessive grease

The aircraft was found to have incorrect grease, Aeroshell 33, on all of its main landing gear axles. However, due to the presence of Aeroshell 22 grease also on the axles, the exact time of the Aeroshell 33 application could not be determined. The most likely event would have been during scheduled lubrication maintenance, not during individual wheel/brake replacement. The location of the Aeroshell 33 grease on the inner area of the axle suggested it had been present for some time. The aircraft involved in the similar incident on 3 July 2004 also had incorrect grease on its landing gear.

During their fleet check, the operator identified two aircraft (the subject accident aircraft and the aircraft from 3 July) that had both the incorrect type and an excessive amount of grease present and two other aircraft that showed signs of excessive or incorrect grease on their axles.

In all the above cases, the aircraft involved had undergone maintenance requiring axle lubrication at the same maintenance facility, at around the same time.

After the November 2000 incident, that maintenance facility had been issued with an alert bulletin addressing landing gear lubrication problems, but an inspection of other aircraft from the operator's fleet was not carried out at that time.

The reason for the application of Aeroshell 33 to the landing gear axles could not be determined, but may have been the result of maintenance personnel not following work procedures correctly, the use of incorrect lubrication equipment, or the use of the correct equipment that had been filled with the incorrect grease.

A number of the operator's aircraft were found to have excessive amounts of grease on their landing gear. Maintenance procedures including the operator's work sheets instructed the wiping away of excess grease after lubrication. Previous maintenance had not complied with that instruction. Failure to remove the excess grease after lubrication tasks led to its build up around the wheels and brake units presenting the potential fire hazard. The aircraft manufacturer's maintenance manual issued warnings of this potential.

2.2.4 Fire initiation

The grease manufacturer confirmed that Aeroshell 33 grease had a lower flash point than the approved Aeroshell 22 axle grease making it more susceptible to ignition under normal braking conditions.

The presence of Aeroshell 33 and excessive amounts of grease on the axles, may have led to a condition where a fire could initiate under normal brake operating temperatures. All wheel axles contained the incorrect grease in excessive amounts and were subjected to the same braking forces, however, only three actually ignited.

The sequence of fire ignition was not consistent with the varying temperatures of the wheels as recorded on the EICAS synoptic screen and the aircraft's quick access recorder. Therefore, the quantity of grease and the peak temperatures reached by the brake units were critical factors for ignition.

2.3 Aircraft evacuation

2.3.1 Evacuation announcement

The timing of the evacuation at the terminal was significant for the resulting actions of the cabin crew and passengers. All of the aircraft's 12 doors had been placed in the disarmed mode prior to the evacuation announcement in readiness for normal disembarkation. All three cabin crew who opened doors while they were still in the disarmed mode during the evacuation had been previously preoccupied with other disembarkation tasks or had moved from their door, which may have contributed to their actions.

During normal arrival procedures, the seatbelt sign was extinguished shortly after the aircraft stopped at the terminal. That action was delayed on this occasion as the flight crew were investigating the brake fire event with the ground engineers. It was not until the CSM advised the flight crew that the signs were still illuminated that they were extinguished.

The expectation of imminent departure from the aircraft led to some passengers standing in the aisles with their cabin baggage while the seatbelt signs were still illuminated, contrary to regulatory requirements (CAO 20-16-3). That action increased the volume of passengers with baggage moving toward the forward exits in the short time between the seatbelt signs being turned off and the evacuation announcement.

2.3.2 Cabin crew action

After commencement of the evacuation, it became difficult for the cabin crew to prevent passengers from evacuating without their personal belongings. The re-direction of passengers from blocked exits, combined with the bags that had been dropped in the aisles at the usable exits, led to increased congestion and pressure on the cabin crew. The movement of passengers onto the slides took priority over the requirement for passengers to remove sharp objects and leave their bags and belongings on the aircraft.

Although the ground engineers signalled the cabin crew to stop the evacuation, cabin crew training required that once initiated, the evacuation would not stop until all occupants were off the aircraft. In addition, the cabin crew were unaware of the nature of the emergency requiring the evacuation, therefore the advice of the ground staff was overruled.

Once the cabin was clear of all the passengers, the cabin crew disembarked onto the aerobridge. That action was contrary to the operator's procedure, which instructed them to evacuate down the slides and assist passengers on the ground. That decision may have been influenced by the actions of the ground engineers and the timing/location of the evacuation.

2.3.3 Flight crew action

The flight crew, in complying with their evacuation procedures, vacated the aircraft, with the copilot deploying down the right upper deck slide holding a 3 kg fire extinguisher. The requirement to carry the fire extinguisher would have contributed to a less stable descent of the copilot and the subsequent shoulder injury sustained. The second officer and PUIT aided the cabin crew in clearing the main deck. Once all the passengers were clear they followed the cabin crew onto the aerobridge. Upon reaching the main cabin, the PIC approached R2 door, but was signalled away by a ground engineer, so he exited the aircraft via the aerobridge and preceded to the ground to assess the situation as required by the operator's procedures.

The decision by the pilot in command to evacuate the aircraft was made in accordance with the operator's procedures.

2.3.4 R3 door slide deflation

The examination of the failed door R3 slide, found there was no evidence of fibre cutting or sharp object penetration. The failure resulted from high pressure sliding contact between the slide and another object over a short distance, leading to fibre overload. The exact source of the pressure could not be determined, but such an action could have occurred from a number of items including the heel of a shoe, or the corner of an object (such as a brief case or cabin bag) carried by an evacuating passenger.

Although the majority of passengers who descended the slide were wearing their footwear, some passengers were also carrying their personal belongings contrary to the operator's evacuation procedures. The passenger who was injured descending the slide at the time it deflated was carrying a soft handbag and was wearing low-heeled shoes.

2.3.5 Use of over-wing slides

The over-wing slide deployment did not directly hamper the ARFFS crew from fighting the fire in the right body landing gear. However, the close proximity of the slide to the wheel well may have presented a problem in the event of a more substantial fire, or if the fire had spread.

The operator's evacuation procedures directed the cabin crew to look through the windows adjacent to their exit for signs of fire. If no fire was evident, they were to open the exit, deploy the slide and commence passenger evacuation.

However, it was not possible to see the landing gear area from the over-wing exits or the adjacent windows. Therefore, during brake fires an accurate assessment of the extent of fire could not be obtained by viewing through the number- three left and right doors or adjacent windows and the potential to evacuate passengers into a fire hazard area existed.

3 CONCLUSIONS

3.1 Findings

Aircraft

1. The aircraft was considered to be in a serviceable condition at the time of the accident.
2. A BRAKE TEMP advisory message on the right body landing gear was indicated after the aircraft parked at the terminal.
3. A fire ignited on the right wing landing gear, followed by two further fires on the right body landing gear.
4. The brake units associated with the fires were found to be worn, but within serviceable limits.
5. The presence of an incorrect grease was found on all of the main landing gear axles.
6. Excessive amounts of grease were observed around the wheels and brake units of all the landing gears.
7. Recorded data indicated that none of the brake units exceeded their safe working temperature or torque.
8. The maintenance equipment used to lubricate the landing gear was not clearly labelled to identify the different types of grease they contained.
9. During the evacuation, three aircraft doors were opened in the disarmed mode.
10. All slides were correctly fitted to the aircraft.
11. The failed R3 slide did not show signs of any pre-existing defects.
12. Failure of the R3 slide was considered to be due to overload of the fabric fibres.

Flight Crew

1. The crew assessed the weather conditions to be within operational limits for landing.
2. An appropriate auto brake selection was made.
3. The PIC advised 'idle reverse thrust only' requirement and placed his hand over the copilot's on the thrust reverser controls.
4. Inadvertent de-selection of reverse thrust occurred during the landing roll.
5. None of the flight crew noticed the de-selection of reverse thrust.
6. Application of manual braking was required to exit the runway at taxiway G.
7. Use of taxiway G minimised the taxi distance to the terminal.
8. The flight crew observed a hot brake indication and reported it to the ground crew.
9. On receiving confirmation of a brake fire, the PIC initiated an evacuation.

10. The flight crew did not advise the cabin crew of the nature of the emergency when the evacuation was announced.
11. The copilot was injured while evacuating down the right upper deck slide while carrying a 3 kg fire extinguisher.

Cabin crew

1. The operator's procedures required the movement of the CSM from door L2 to door L1, for disembarkation duties.
2. Following door L2 being vacated by the CSM, there were no procedures in place for the formal take over of that door by another cabin crewmember.
3. Some cabin crew did not control passengers leaving their seats while the seatbelt signs were illuminated.
4. Some passengers were not prevented from evacuating with cabin baggage.
5. The cabin crew did not evacuate the aircraft to assist the passengers on the ground.

Aircraft Maintenance Engineers

1. Poor or inadequate maintenance practices during lubrication of the landing gear resulted in the presence of incorrect and excessive amounts of grease on the landing gear wheels and brakes.

Other Ground staff

1. There was no training provided to the ground staff for aircraft emergency evacuation situations at airport terminals.

3.2 Significant factors

Flight crew actions

1. The inadvertent de-selection of reverse thrust.
2. The flight crew failed to detect the de-selection of reverse thrust.
3. The flight crew's decision to utilise taxiway G to minimise the taxi distance led to the requirement of additional manual braking during the latter part of the landing roll.

Brake fire.

1. Incorrect grease of a lower flash point was applied to the landing gear axles during maintenance.
2. Excessive amounts of grease were present on landing gear wheels and brake voids.
3. The worn brake units generated a higher peak temperature over a short time frame.
4. The inadvertent de-selection of reverse thrust during the landing roll resulted in increased auto-brake and manual brake applications.

5. The use of runway 34L and taxiway G minimised the taxi distance to the terminal reducing the effective brake unit cooling time.

Evacuation and slide failure.

1. Passengers standing in the aisles with cabin baggage at the time of the evacuation announcement caused congestion.
2. A number of passengers evacuated down the slide in possession of their cabin baggage and personal belongings.
3. During passenger evacuation the R3 slide sustained an overload failure of it's fabric fibres when punctured by a blunt edged object.
4. The use of the over-wing slides during the evacuation, presented passengers with the potential hazard of being placed in close proximity to the fire source.

4 SAFETY ACTION

Operator's safety action

The operator advised the ATSB that subsequent to this accident it has implemented a number of safety actions that include:

Aeroshell 22 and Aeroshell 33 grease are now obtained in uniquely identified cartridges. All grease application equipment and their storage containers are now clearly identified through colour coding and labelling specific to the grease type.

Maintenance memo M0429-GEN-32-41-JUL 10/03 has been issued, to highlight the hazards and precautions to be taken when carrying out wheel and brake assembly lubrications.

Training videos from grease manufacturers have been sourced and operator's newsletters have been issued to further educate the work force.

A review of the aircraft maintenance manual, chapters 12 (landing gear-lubrication) and 32 (wheel and brake – removal/installation) was carried out to ensure the correct greases are specified and that appropriate warnings are listed.

The drafting of a 'Safety Alert' memo providing guidelines to ground engineers for non-normal receipt and dispatch of aircraft.

The amendment of the aircrew emergency procedures manual (AEPM) to remove the requirement for the copilot to carry a 3kg fire extinguisher when evacuating the aircraft and an amendment of section 5.4 to include the statement 'cabin baggage must be left on the aircraft', with this emphasis being give to cabin crew during training.

The amendment of the Cabin Crew Operations Manual (CCOM) to read, 'PAs regarding the requirement for passengers to remain seated with seatbelts fastened may require re-enforcement. In the event passengers disregard this PA, Cabin Crew must direct passengers to return to their seats and keep seatbelts fastened. Cabin Crew movement should be restricted to that which is safety related only'. This has been reinforced during cabin crew training.

The CSM's role at door L2, is to be changed from the 'primary' to the 'assist' during the ongoing refurbishment of the operator's Boeing 747 fleet.

The amendment of the flight crew training manual to incorporate the following statements, 'the PNF [pilot not flying] should monitor engine operating limits and call out any engine operational limits being approached or exceeded, any thrust reverser failure or any other abnormalities.' and, 'The PNF should also call out any inadvertent selection of forward thrust as reverse thrust is cancelled.'

Safety Recommendations

In addition to the safety actions carried out by the operator, the ATSB is issuing the following safety recommendations:

Safety Recommendation R20050003

The Australian Transport Safety Bureau recommends that Qantas Airways Ltd, review the adequacy of their procedures for the deployment of over-wing slides during known brake fire situations. This review should take into consideration the visual cues used and potential risk to passengers of evacuating within close proximity of a fire zone.

Safety Recommendation R20050004

The Australian Transport Safety Bureau recommends that the Civil Aviation Safety Authority, review the adequacy of operator procedures for the deployment of over-wing slides during known brake fire situations. This review should take into consideration the visual cues used and potential risk to passengers of evacuating within close proximity of a fire zone.

APPENDIX

Appendix- A

Department of Transport and Regional Services

Australian Transport Safety Bureau

TECHNICAL ANALYSIS REPORT

26/03

Boeing 747-400, VH-OJU

Deflation of Right Over-wing Escape Slide

Dr A Romeyn

1. Introduction

Passengers were evacuated from a Boeing 747, VH-OJU, via the emergency escape slides, after the crew was notified of a fire in the main landing gear brake units. During the process of passenger evacuation, over-wing slide R3 deflated.

The aircraft had landed at Sydney Airport on 2 July 2003 and was stationary at gate 33, when ground staff noticed at least two flash fires.

Figure 1: Video frame showing one of the flash fires in the main landing gear



This report addresses the structural failure of over-wing slide R3.

2. Timing of slide deflation

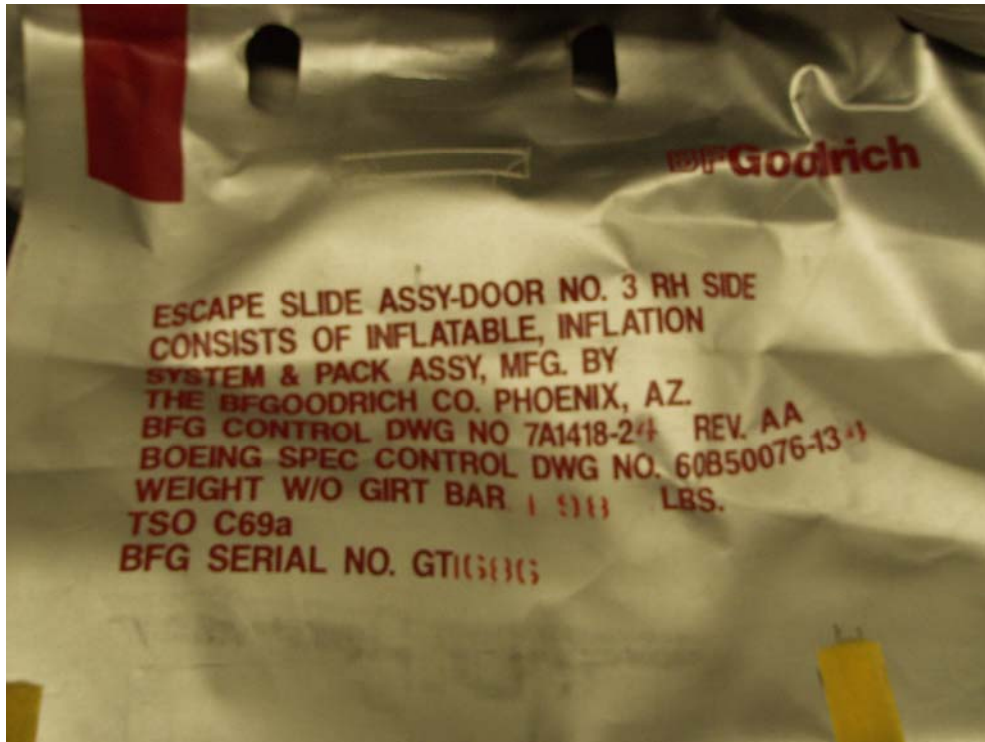
The evacuation of the aircraft was captured by a video surveillance system. The video recording of the events at gate 33 was discontinuous as the surveillance system comprised multiple cameras covering a number of locations. However, the recovered video frames of the events at gate 33 were annotated with a time stamp.

A time interval of 32 seconds elapsed between slide deployment to slide deflation. It was apparent from the video frames that a number of passengers had used the slide before its deflation and that a passenger was on the slide when it deflated.

3. Structural failure of over-wing slide R3

Escape slides on Boeing 747 aircraft are constructed from a polyurethane coated polymeric fabric. The slides are self-supporting structures, with support being provided by gas-inflated integral tubes. The over-wing slide comprises two slideways separated by an inflated central tube and bounded by outer inflated tubes. A heavy fabric is used to reinforce the slideway. This reinforcing does not extend over the central or outer tubes.

Figure 2: Escape slide serial number and construction details



Visual examination of the escape slide material did not reveal any indication of fabric proofing deterioration or fabric fibre deterioration.

The deflation of the slide occurred as a result of a longitudinal tear in the central tube in the section of the slide extending from the wing trailing edge to the ground. The location and features of the tearing in the slide are shown in Figure 3. The length of the longitudinal tear was 154 cm. A small transverse tear, extending 2.8 cm from the longitudinal tear to the right slideway reinforcement, was located 71 cm from the upper end of the longitudinal tear.

Microscopic examination of the features associated with the tear revealed that both the longitudinal and transverse tears were aligned with the weave of the fabric. Tearing occurred by the tensile fracture of fibres comprising the warp or weft of the fabric.

The immediate region of the junction of the longitudinal and transverse tear was examined microscopically with light and scanning electron microscopes (see Figure 4). A small section was cut from the slide to allow the microscopic examination of the region immediately surrounding the transverse tear. The most significant feature observed was the abrasion of the raised portions of the weave on the upper side of the transverse/longitudinal tear corner. A feature that indicates that sliding contact between

the slide and another object occurred under high contact pressure over a short distance. In addition, no evidence of fibre cutting or sharp edged object penetration was observed.

Figure 3: Overview of tearing in the R3 slide, Detail of transverse tear inlayed

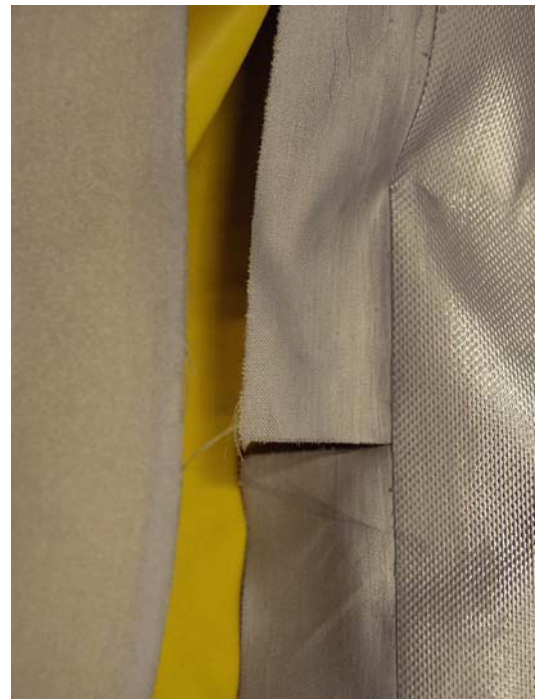
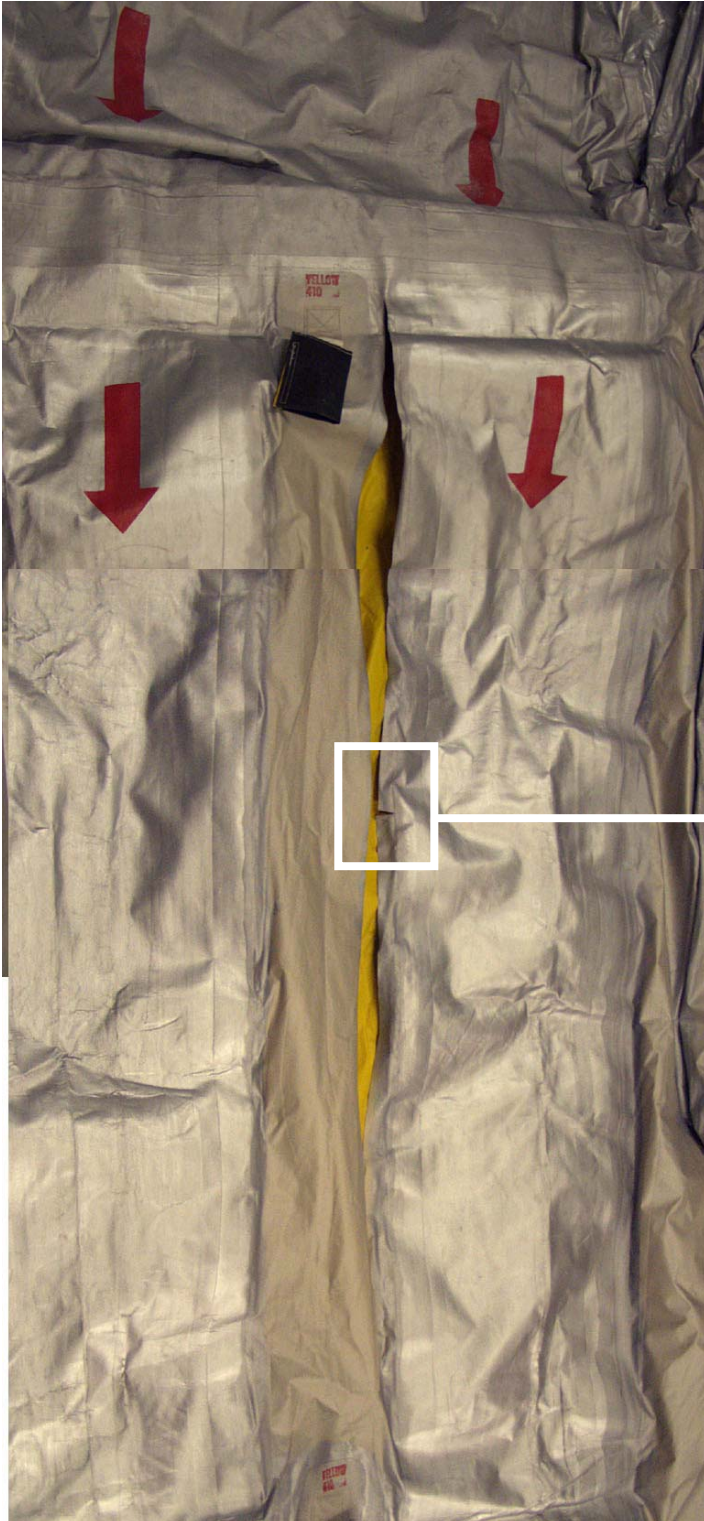
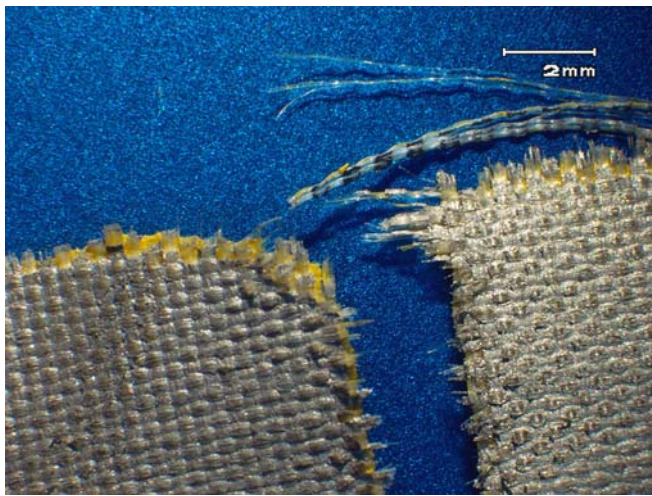
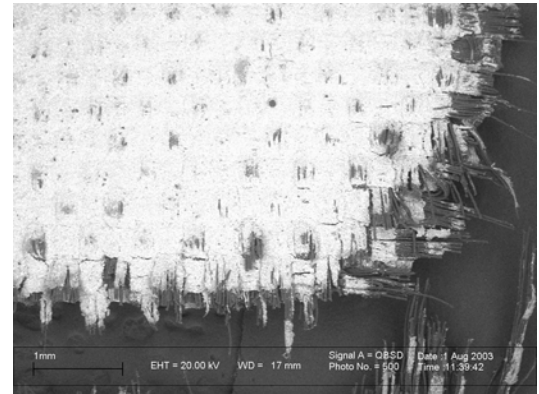


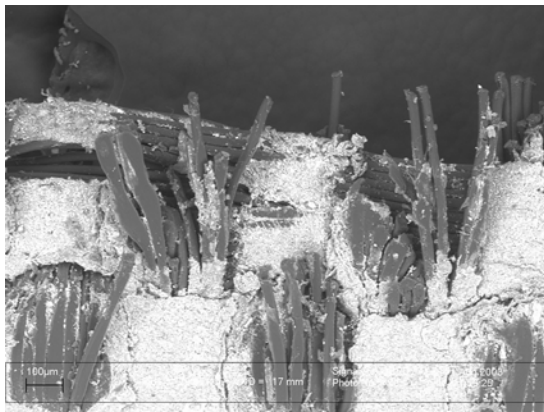
Figure 4: Examples of the features present at the junction of the longitudinal and transverse tears



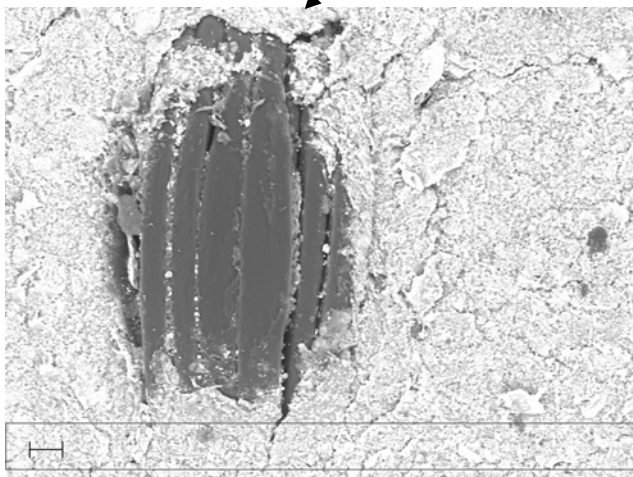
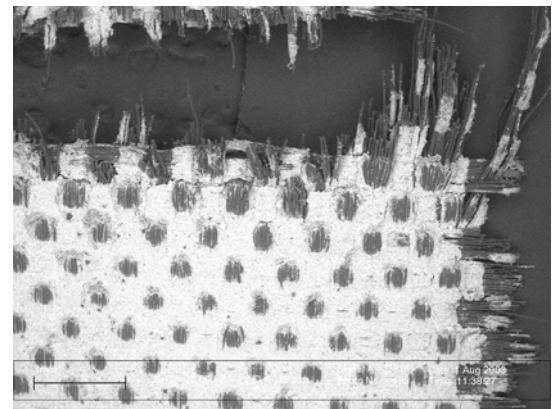
Direction of sliding



Direction of sliding



Weave damage on the upper side of the transverse tear



4. Conclusions

The over-wing escape slide R3 deflated after the slide had been used by a number of passengers. Video evidence established that the slide deflated 32 seconds after inflation.

The site of the tear initiation was established to be the junction of the longitudinal and transverse tears. This conclusion is based on an examination of fibre fracture and fabric proofing fracture.

Macroscopic and microscopic examination of the site of tear initiation revealed that the fabric of the central tube had been abraded over a short distance on the upper side of the longitudinal/transverse tear junction prior to the initiation of fabric tearing and pressure release. This surface abrasion is consistent with sliding contact between the slide and a blunt edged object in the direction of sliding from the wing to the ground.