RNF

AIRCRAFT ACCIDENT REPORT

Report by the General Civil Aviation Authority of the United Arab Emirates. Report on the accident involving Air Atlanta Icelandic boeing 747-230C,registration TF-ARR at Sharjah International airport, United Arab Emirates on 07th november, 2004.

M-08004/AIG-37

TF-ARR
Boeing 747-230C
Sharjah International airport, UAE
07th November 2004

AIRCRAFT ACCIDENT 04/04

REPORT
ON THE ACCIDENT INVOLVING
AIR ATLANTA ICELANDIC
BOEING 747-230C,
REGISTRATION TF-ARR
AT
SHARJAH INTERNATIONAL AIRPORT,
UNITED ARAB EMIRATES
ON 07th NOVEMBER, 2004

AIRCRAFT ACCIDENT 04/04

OBJECTIVE

In accordance with Annex 13 to the Convention on International Civil Aviation, it is not the purpose of aircraft accident investigation to apportion blame or liability. The sole objective of the investigation and the Final Report is the prevention of accidents and incidents.

TABLE OF CONTENTS

ABBREVIATIONS USED IN THIS REPORT

agl	Above Ground Level
amsl	Above Mean Sea Level
ALS	Aircraft Landing System
ATC	Air Traffic Control
ASDA	Accelerate Stop Distance Available
CAA	Civil Aviation Authority (Iceland)
cm	centimetre(s)
CRM	Crew Resource Management
CVR	Cockpit Voice Recorder
FDR	Flight Data Recorder
GCAA	General Civil Aviation Authority (UAE)
ft	feet
hr	hour(s)
hPa	Hectopascals
IB	In Board
ICAO	International Civil Aviation Organization
kg	Kilogram(s)
km	Kilometre(s)
kt	Knots
KIAS	Indicated Air Speed
KCAS	Calibrated Air Speed
m	Metre(s)
M	Magnetic (heading)
MHz	Megahertz
min	Minute(s)

mm	Millimetre(s)
nm	Nautical Mile(s)
OB	Out Board
PF	Pilot flying
PNF	Pilot not flying
QNH	Setting on altimeter sub scale to indicate altitude above mean sea Level
RESA	Runway End Safety Area
RFF	Rescue and Fire Fighting
sec	Second(s)
SHJ	Sharjah Aeronautical Designator
SOP	Standard Operating Procedure(s) (operator)
TODA	Take-Off Distance Available
UAE	United Arab Emirates
UTC	Coordinated Universal Time
V_1	Take-Off Decision Speed[1]
V_r	Rotation Speed
V_2	Take-Off Safety Speed[2]
V_{EF}	The speed at which the critical engine is assumed to fail during takeoff.
VMC	Visual Meteorological Conditions
VOR	VHF Omni-directional Radio Range

INTRODUCTION

SYNOPSIS

[1] The maximum speed in the takeoff at which the pilot must take the first action (e.g., apply brakes, reduce thrust, deploy speed brakes) to stop the aircraft within the accelerate-stop distance. V_1 also means the minimum speed in the takeoff, following a failure of the critical engine at V_{EF}, at which the pilot can continue the takeoff and achieve the required height above the takeoff surface within the takeoff distance. Any problems after V_1 are treated as in-flight emergencies.

[2] Also called takeoff screen speed, the minimum speed in the second segment of a climb following an engine failure.

The aircraft involved was a Boeing 747-230C, owned and operated by Air Atlanta Icelandic on a wet lease agreement with Lufthansa. Iceland was the State of Registry/Operator and the US was the State of Design and State of the Manufacturer.

The aircraft was operating a cargo flight, DLH8457, from Sharjah International Airport, U.A.E. to Frankfurt International Airport, Germany. The accident occurred as a result of an aborted take off at above V_1 speed which led to a runway excursion. The aircraft stopped slightly after the end of the opposite runway, suffered major damage, but all crew escaped unhurt.

A post accident aircraft inspection found the No 9 wheel of the Right Body Landing Gear had suffered a broken wheel rim, brake and a burst tyre. The No 10 and 12 wheels of the same gear had their tyres blown as well.

Eight (8) safety recommendations have been made. Unless otherwise indicated, recommendations in this report are addressed to the regulatory authority of the State having responsibility for the matters with which the recommendation is concerned. It is for the authority concerned to decide what action is taken.

DETAILS

The accident details are as follows;

Registered Owner	:	Air Atlanta Icelandic
Registered Operator:	Air Atlanta Icelandic	
Aircraft type & model	:	Boeing 747-230C
Nationality	:	Iceland
Registration	:	TF-ARR
Place of Accident	:	Western side, near threshold Runway 12, Sharjah International Airport, United Arab Emirates
Date & Time	:	07th November, 2004 1635 hours local UAE time 07th November, 2004 1235 hours UTC

Note: Unless otherwise stated, all times in this report are local UAE time, which is Coordinated Universal Time (UTC) plus 4 hours.

Persons on board	:	4 Flight crew
Fatalities	:	Nil
Injuries	:	Nil

ORGANIZATION OF THE INVESTIGATION

The GCAA was notified within minutes of the accident and an Aircraft Accident Investigation Committee was established under a Ministerial Decree identifying the GCAA

as the authority responsible for the conduct of the investigation. Notification to ICAO and applicable States was completed on the day after the accident.

Mr. Ahmed Al Haddabi Director Aviation Safety and Security	-	Investigator-In-Charge
Mr. Owsi Al Khanjari Chief Regulation and Investigation	-	Investigator on airworthiness matters
Captain Mahamad Bin Dan Incident Investigation & Regulatory Officer	-	Investigator on flight operation matters and Accident Coordinator

Officials from the following State of Registry/Operator, State of Design and Manufacturer of the aircraft were granted Accredited Representation in accordance with ICAO Annex 13 and corresponding UAE Civil Aviation Regulations. Officials representing the manufacturer of aircraft and engines also assisted in the investigation and were granted observer status.

State of Operator/Registration	-	Icelandic AAIB
State of Design/Manufacture (aircraft)	-	USA NTSB
State of Manufacture (engine)	-	USA NTSB

GCAA Investigators examined the site of the accident to secure material evidence which was later removed to a secure site within Sharjah International Airport. The UK AAIB was requested to provide assistance with the flight recorders read outs and analysis and this was conducted within two weeks of the accident. Remnants of the wheel rim, brake and other associated components of the No 9 Wheel Assembly from the Right Body Landing Gear were sent to the wheel manufacturer, Honeywell ALS, via the NTSB for laboratory analysis.

The technical investigation was closely coordinated and controlled by the GCAA during the initial onsite investigation and the collection of technical information, FDR/CVR readouts, as well as the examination of the components removed from the aircraft.

The first factual findings of the investigation were published in an ADREP Preliminary Report issued on 01st December, 2004.

FINAL REPORT

This Final Report is released by the GCAA on 19th April 2006 under the authority of the GCAA Chairman of the Board.

1. FACTUAL INFORMATION

1.1 History of the flight

1.1.1 The aircraft and crew were assigned to operate a cargo flight, DLH8457, from Sharjah, U.A.E. to Frankfurt, Germany. The crew did not notice anything unusual with the aircraft apart from a few known defects verbally reported by the crew that operated the previous sector from Bangkok. The aircraft was then prepared for the flight to Frankfurt and the crew completed pre-departure checks including an external inspection of the aircraft.

1.1.2 After push back and engines start-up, at 1623:24 hr the crew was cleared by ATC to taxi the aircraft to runway 30. From the performance and speed reference cards the crew ascertained the decision speeds for a reduced engine thrust 10º flap take-off as follows; V_1 – 162 KIAS, V_r – 174 KIAS and V_2 – 180 KIAS. The crew line-up the aircraft for a full length take-off and was cleared for take-off at 1631:42 hr. A surface wind check of 340º/08 kt was passed by the tower controller.

1.1.3 The take-off roll commenced at 1633:32 hr. During the roll, the FO made the 80 KIAS call at 1633:57 hr followed by the V_1 call 26 seconds later. At the same time of the V_1 call, the tower controller transmitted to the crew "and Lufthansa there was a bang and you've got smoke coming on the right hand side". The commander then aborted the take-off at 1634:26 hrs whilst maintaining the aircraft on the runway centreline. The speed of the aircraft when aborting actions were first initiated by the crew was 165 KIAS.

1.1.4 The crew indicated that the power levers were brought to idle, full reverse thrust selected, speed brakes deployed and manual application of brakes were made. The aircraft acceleration however, continued to 171 KIAS before decelerating normally but was not able to come to a halt within the accelerate stop distance available.

1.1.5 Just prior to reaching the end of the runway, the commander turned the aircraft to the left to avoid the elevated approach lights at the end of the runway and it came to a stop in an open sand area approximately 30 metres from the prepared surface of the runway in a nose low attitude. The commander then ordered an evacuation and the crew exited through the right upper deck door using ladders provided by personnel from the airport RFF services.

Place of Accident:	Sharjah International Airport, United Arab Emirates Western side near threshold Runway 12	
	Latitude	: 25º 20' 18" N
	Longitude	: 055º 29' 54" E
	Elevation	: 111 ft amsl
Date & Time :	07th November 2004 1635 hours local UAE time 07th November 2004 1235 hours UTC	

1.2 Injuries to persons

Injuries	Crew	Passengers	Others
Fatal	0	0	0
Serious	0	0	0
Minor	0	0	0
None	4	0	0

1.3 Damage to aircraft

The aircraft suffered substantial damage to the fuselage, wings and the landing gears. With the exception of the Right Body Landing Gear, the damage sustained by the other landing gears was directly due to the aircraft leaving the prepared surface onto the sandy area off the left edge at the end of the runway.

The Right Body Landing Gear sustained the following damage; Wheel No. 9 (front left wheel) was badly damaged with the Inboard Wheel half and brake unit missing leaving whatever was left of the tyre part. The Inboard Wheel half and pieces from the wheel's brake unit and system were found along the runway.

Wheel No.10 (front right wheel) rim and brake unit were intact, however, the tyre was blown and completely missing. Wheel No.12 (aft right wheel) rim and brake units were intact with the tyre blown and part of it missing. Wheel No. 11 remain intact wholly.

1.4 Other damage

One aerial of the aerodrome localiser was damaged that rendered the airport's ILS facility unserviceable. The nose of the aircraft had narrowly missed the localiser hut by a few inches and was resting on the corner of the building. However, there was no obvious damage to the building.

Scrape marks were evident along the length of the runway on the alignment of the right body gear approximately starting from a point at 1,170 m from threshold 30 and leading to the aircraft final location.

1.5 Personnel information

1.5.1 General.

The required flight crew complement for the Boeing 747-230C was a Captain, First Officer and Flight Engineer.

1.5.2 Commander : German National
Male 56 years

Licence : Icelandic ATP Licence No. 3311001793
Valid to 11th February, 2006
B747 100-300 command type rating

	Medical Certificate	:	Class 1 valid until 22nd January, 2005
	Flying experience	:	Total all types - 21430:00 hours Total on B747 100-300 - 430:00 hours Last 30 days on B747 - 20:30 hours Last 24 hours on B747 - 7:34 hours
	Duty Times	:	Last 7 days - 20:21 hours Last 48 hours - 12:26 hours
1.5.3	First Officer	:	Icelandic National Male aged 43 years
	Licence	:	JAR-FCL CPL Licence No.IS CPL/A 1955 B747 100-300 co-pilot type rating with IR Valid to 03rd September, 2007
	Medical Certificate	:	Valid until 22nd December, 2004
	Flying experience	:	Total all types - 4230:00 hours Total on B747 100-300 - 1547:00 hours Last 30 days on B747 - 46:00 hours Last 24 hours on B747 - 7:34 hours
	Duty Times	:	Last 7 days - 29:41hours Last 48 hours - 12:26 hours
1.5.4	Check Flight Engineer:		South African National Male aged 40 years
	Licence	:	Icelandic Validation No 1078E valid to 16th July 2005 on South African FE licence No 482
	Medical Certificate	:	Valid until 31st July 2005
	Flying experience	:	Total all types - 4562:00 hours Total on B747 100-300 - 3132:00 hours Last 30 days on B747 - 78:39 hours Last 24 hours on B747 - 7:34 hours
	Duty Times	:	Last 7 days - 16:26 hours Last 48 hours - 12:26 hours
1.5.5	Flight Engineer	:	South African National Male aged 63 years
	Licence	:	Icelandic Validation No 1489E valid to 19th October 2005 on South African FE licence No 137

Medical Certificate	:	Valid until 02nd December 2004	
Flying experience	:	Total all types	- 18014:00 hours
		Total on B747 100-300	- 17742:00 hours
		Last 30 days on B747	- 30:43 hours
		Last 24 hours on B747	- 7:34 hours
Duty Times	:	Last 7 days	- 12:26 hours
		Last 48 hours	- 12:26 hours

1.6 Aircraft Information

1.6.1 Aircraft Details

Type	:	Boeing 747-230C
Serial No.	:	23621
Engines	:	General Electric CF6-50E2 No 1 – Serial No 517426 No 2 – Serial No 530295 No 3 – Serial No 517520 No 4 – Serial No 530256
Certification of Registration	:	Registered in Iceland as TF-ARR
Certificate of Airworthiness	:	Issued on 25th June 2004 Valid to 30th June 2005
Operator in-service date	:	25th June 2004
Total airframe hours	:	79,733 hrs
Total cycles	:	13,833
Fuel on board on take-off	:	93.6 tonne
Actual TOW on departure	:	354.68 tonne

1.6.2 Maintenance Details

Maintenance checks performed in accordance with the manufacturer's Maintenance Schedule for B747-230C were as follows:

Type of Check	Date Performed	Airframe Hours	Next Due
A1	22nd October 2004	79,552	80,052
A2	08th September 2004	79,047	80,047
A3	22nd October 2004	79,552	80,552
A4	26th June 2004	78,165	80,165
C1	29th August 2003	74,687	80,187
C2	29th August 2003	74,687	85,687
C3	29th August 2003	74,687	90,187
C4	29th August 2003	74,687	96,687

Landing Gear Status

Landing Gear	Part No	Serial No	TBO (days)	TSO	O/H Due
Nose	65B01465-3	CP000319	3650	Aug 2000	Aug 2010
Left Wing	65B01464-45	CP000627	3650	Aug 2000	Aug 2010

Right Wing	65B01464-46	CP000628	3650	Aug 2000	Aug 2010
Left Body	65B01466-23	CP000631	3650	Aug 2000	Aug 2010
Right Body	65B01466-24	CP000632	3650	Aug 2000	Aug 2010
Brakes	2605662-3	Honeywell	OC	Every time in shop	
Wheels	2607081 2603561	Honeywell	OC	Every 3rd time in shop	

All Mandatory Airworthiness Directives had been complied with.

1.6.3 Technical Considerations.

The aircraft Journey and Log Book indicated that the aircraft had nil carried over defects since the last daily inspection carried out on 07th November 2004. The Aircraft Technical Flight Log indicated that the aircraft was serviceable at the last departure aerodrome of Bangkok on the same date.

The last weekly check was conducted on 02nd November 2004 at Frankfurt and included checks on all landing gears and wheel wells.

1.6.4 Operational details

A review of the operational documentation indicated that the crew had all information available for flight planning prior to departure and there were no abnormalities found. The Air Atlanta Weight and Balance Manifest is a combination of the load sheet with the weight and balance sheet and reflected the actual load of the aircraft. The details for this flight from Sharjah to Frankfurt were as follows;

Dry Operating Weight	-	155,920 kg
Total Traffic Load	-	105,160 kg
Zero Fuel Weight	-	261,080 kg
Fuel	-	93,600 kg
Take-off Weight	-	354,680 kg
Calculated % TO MAC	-	23, 09
Estimated trip fuel	-	75,034 kg
Estimated Landing Weight	-	279,646 kg
Estimated % LDG MAC	-	25, 71

1.6.5 Failed Wheel (No 9 Wheel).

1.6.5.1 General.

The details of the failed wheel are as follows:

Part Name	Part Number	S/Number	Mfg Date	Last O/H	Date Installed
OB Wheel	2607081-2	H15229	11/93	16.09.04	28.09.04
IB Wheel	2607081-1	1229	8/82	NA	28.09.04
Brake	2605662-3	B0347	9/77	NA	28.09.04

Landings since last overhaul: 90

1.6.5.2 Previous Modification and Inspection Requirements.

Honeywell ALS issued a Service Bulletin Number 2607081-32-030 Revision 3 dated 31st May 2001 requiring operators to perform eddy current or ultrasonic inspection of key bosses at each tyre change. This requirement had been carried out for this particular wheel.

The Service Bulletin also recommended that inboard wheels manufactured in 1982 to be retired at the operator earliest convenience. According to the table given in the Service Bulletin, all Inboard wheels with Part Numbers 2607081-1/2/3 manufactured through 1982 should be retired during the year 2000.

1.7 Meteorological Information.

1.7.1 Weather Conditions.

1.7.1.1 Sharjah Weather Report (Forecast).

The forecast issued at 1200 UTC on 07th November, 2004 was 34008KT 310V030 CAVOK 32/15 Q1012=.

The forecast issued at 1230 UTC on 07th November, 2004 was 35007KT 320V060 CAVOK 32/15 Q1012=.

1.7.1.2 Sharjah Weather Report (Actual). The weather conditions recorded at 1223 hours UTC and at 1230 hours UTC, were the same as recorded on the Airfield Terminal information Service (ATIS);

		1223 hours UTC		1230 hours UTC
Wind	:	340º/08 kt	:	350º/07 kt
Visibility	:	> 10000 m	:	>10000 m
Cloud	:	nil	:	nil
Temperature	:	32º/15º	:	32º/15º
QNH	:	1012	:	1012
Warnings	:	Nil	:	Nil

1.8 Aids to Navigation.

1.8.1 Navigation Aids.

The navigation aids at Sharjah are VOR/DME for runway 12 as well as an ILS for runway 30. They conform to, and are in compliance with, Annex 10, Volume 1, Radio Navigation Aids. The runway 12 VOR/DME was operating on 112.30 MHz and there was no known unserviceability or abnormality prior to the accident.

1.9 Communications.

All transmissions to the aircraft, as well as inter-agency telephone conversations, made by UAE ATC were clear, in the English language, and recorded. Transcripts were made of all communications involving DLH 8457 and the control tower. The UTC timing on the tapes was determined to be correct UTC time. All instructions issued by ATC were correctly acknowledged by DLH 8457.

1.10 Aerodrome Information.

1.10.1 Aerodrome

Sharjah International Airport is a UAE international airport with full facilities. Runway 30 is aligned at 301° M and dimensions are 4060 m x 45 m with a Take-Off Distance Available of 4220 m. The designated accelerate-stop distance available (ASDA) is 4060 m.

The elevated approach lights and their supporting structures for the approach to Runway 12 which are located within the RESA for Runway 30 were not frangible and did not meet the requirements of Chapter 9 in ICAO Annex 14 (Aerodromes).

1.10.2 Air Traffic Control.

At the time of the accident the control tower was manned by correctly licensed and validated personnel.

1.10.3 Fire Services.

Sharjah Airport Fire Services are categorised as RFF Category 9. The RFF facility was determined to be operating to RFF Category 9 at the time of the accident.

1.11 Flight recorders

1.11.1 Flight Data Recorder.

The Flight Data Recorder fitted was a Fairchild Model FA2100, S/N 000103621 with a recording duration of 270 hours. A total of 62 parameters were recorded. The download was carried out using AAIB download facilities at Aldershot in the UK and good quality data was obtained. The FDR was not capable of recording any information on the aircraft anti-skid and brake systems.

A plot of selected parameters is shown at Appendix A.

1.11.2 Cockpit Voice Recorder.

The aircraft was fitted with a Fairchild Model A100A, S/N 52583 Cockpit Voice Recorder capable of recording 4 parallel tracks of information on an endless

loop of tape with a recording duration of 30 minutes. The tape was removed from the recorder for replay and it was found 3 tracks contained useful information although the cockpit area microphone was recorded at slightly low level.

1.11.3 Interpretation of Data.

Information from the FDR indicated that the take-off was aborted at 165 KIAS. Recorded parameters of the aircraft engines EGT and N1 indicated that the power levers were throttled back after this speed however, the aircraft continued to accelerate to 171 KIAS before indicating a gradual reduction in the aircraft speed. The graph shows the deceleration was rapid initially at -0.33 g until 121 KCAS when it then reduced to -0.2 g at 88 KCAS and remained constant until the aircraft stopped. The data recorded also indicated a thrust setting of 112% and EGT readings of 940ºC for the take-off. The airspeed system does not indicate below 49 knots KCAS.

Information from the FDR indicated that the aircraft accelerated at 0.22 g. Referring to the graph at Appendix A, a thrust setting with EGT readings of 940ºC and N1 of 112% were set. The aircraft travelled a distance of 332 metres when the aircraft achieved a speed of 80 KIAS and a time of 25 seconds. At 162 KIAS, the computed V_1 speed, the aircraft travelled a distance of 1830 m and a time of 49 seconds. At 171 KIAS (176 KCAS), the maximum speed recorded, the aircraft had travelled 2250 m with a time of 55 seconds.

The recordings indicated that after 165 KIAS, the thrusts reversals were deployed, the EGT and N1 readings reduced but the aircraft continued to accelerate to 171 KIAS before decelerating.

Data from the previous take-off from Sharjah on 06th November 2004 when the aircraft departed for Hong Kong was also examined to compare the rate of acceleration for the take-off and attached as appendix B. The comparison indicated that the rate of acceleration for both take-offs were identical from when the aircraft achieved the speed of 51 KCAS to the speed of 176 KCAS albeit the rate of acceleration for the take-off on 07th November 2004 was noted to be slightly slower by an average of 3 KCAS per sec.

The CVR recorded a thump sound 3 sec after the FO called 80 KIAS during the take-off roll followed by a second louder thump sound and 'flapping-like' noises 7 sec before he made the V_1 call. The CVR also recorded the commander was saying "that's OK" after the first thump sound. The CVR recorded the commander transmitting the abort take-off call 6 sec after the ATC informed the crew of bang and smoke.

Assuming that all factors affecting the accelerate stop distance required were normal e.g. take-off and braking techniques, line up position etc., the following table shows the summary of the sequence of events taken from the CVR and FDR (versus time, distance and calls).

Time (min:sec)	Time (LT)	Event	Speed (KIAS)	Distance Travelled	ASDA (m)	Full Length (m)

				(±50 m)		
0:0	1633:32	Brake Release/Set Thrust	0	0	4060	4220
0:25	1633:57	FO made 80 knots Call	80	332	3728	3888
0:28	1634:00	1st Thump Sound	85	500	3560	3720
0:44	1634:16	2nd Louder Thump Sound	143	1450	2610	2770
0:51	1634:23	FO made V_1 Call/ATC Transmission of 'Bang'	162	1830	2230	2390
0:54	1634:26	Aborting Actions Initiated	165	2250	1810	1970
0:57	1634:29	Max Speed Achieved	171	2500	1560	1720
1:13	1634:45	1st Max Braking Interphone	84	3500	560	720
1:23	1634:55	2nd Max Braking Interphone	52	3850	210	370

1.12 Wreckage And Impact Information

1.12.1 Runway marks and impact parameters

After the accident, the Investigating team carried out a runway inspection and discovered several components of the aircraft wheel rim, brakes and pieces of rubber on both sides of the runway. Examination of the runway found scrapping marks along the track of the Right Body Landing Gear parallel to the centreline and continued through the intended turn to the left. There were however, no rubber or tyre marks throughout the length of the runway along the aircraft track.

The first evidence of tyre burst was visible at 1,140 metres from threshold 30 to the right of centreline. The first scrape mark on the runway was visible at 1,170 metres from threshold 30 to the right of centreline. Part of brake equiliser rod was found at 1,150 metres from threshold 30 on left of runway. Part of gear door was found at 1,190 metres from threshold 30 on right of runway. Some small wheel parts were found at 1,600 metres from threshold 30 to the right of centreline. Pieces of wheel rim, rubber and associated brake components at 1,900 metres from threshold 30 to the right of runway centreline. A lot of rubber from blown tyres was found at 2040 metres from threshold 30 across the runway.

Continuous scrapping mark on the runway was visible at 3000 metres onwards from threshold runway 30. Measurements taken had identified that these marks had been cut into the runway surface by the aircraft No 9 and 10 wheel rims.

1.12.2 Aircraft examination

1.12.2.1 On Site Examination.

The aircraft was examined in-situ on the day of the accident at Sharjah International Airport. It had come to rest on the sloping sand ground approximately 30 m from the prepared surface left of the end of runway 30.

Major damage to the airframe was observed comprising direct damage to the fuselage, landing gears, inboard flaps and the No 3 engine assembly due to

contact with the ground. The nose-wheel assembly was bent backwards along with the Right and Left Wing Landing Gears.

The Right Body Landing Gear was inspected with the following observations. Wheel No.9 (front left wheel), OB wheel rim and brake unit visible. Tyre was missing. Wheel No.10 (front right wheel) rim and brake unit appear to be intact. Tyre was missing. Wheel No.11 (aft left wheel) wheel was intact. Wheel No.12 (aft right wheel) rim and brake unit intact. Half of tyre was missing.

All thrust reversers were retracted except the No. 3 engine.

There had been no release of fuel and no evidence of fire.

1.12.2.2 Metallurgical Examination.

The fractured wheel assembly, tyres and brake assembly fragments from the No. 9 position were returned to Honeywell ALS for investigation and laboratory analysis through the NTSB. The investigation and laboratory analysis report produced by Honeywell ALS was used in this investigation and attached as Appendix C to this report.

1.13 Medical Information

Investigation of the crewmembers' medical history confirmed that they met the CAA and ICAO Annex 1 medical standards for exercising the privileges of the respective licences held. All four crew were sent to the clinic for medical check-up and found to be normal. There were no indications of any disorder that could have had a bearing on this accident.

1.14 Fire

There was no fire.

1.15 Survival Aspects

The crew evacuated from the right upper deck door. The crew were unable to deploy the door slide because the localiser building was directly beneath it. The crew egress from the aircraft using two ladders provided by the airport RFF, positioning one to the top of the building and the other from the top of the building to the aircraft right upper deck door.

1.16 Statements

1.16.1 Crew.

A post accident interview with all four (4) flight crew members was conducted on the following day of the accident. The crew were very cooperative when supplying information which greatly assisted to further the progress of the investigation. The crew unanimously agreed that they felt the aircraft shaking

during the take-off roll. However, the commander stated that this shaking was normal for a rough runway.

The crew also confirmed that they did not hear any explosion from inside the cockpit. However, they noted that the shaking got heavier approaching V_1 but reacted only when ATC transmitted 'bang and smoke" at around that speed at which point the Commander decided to abort the take-off. The Commander confirmed that he maintained the aircraft on the runway heading and waited to the final moment so that the aircraft speed will be as low as possible before turning the aircraft off to the left side of the runway to avoid the elevated approach lights at the end of the runway.

The Commander confirmed that his take-off briefing to the crew was to abort the take-off in the event of abnormalities if the aircraft speed was below V_1 and to continue with the take-off if above. The Commander also believed that he heard the word 'fire' mentioned by ATC which he said reminded him of the Concorde accident.

The FO recalled that he did the 80 kt and V_1 calls as well as calling out the aircraft speed and time when the Commander aborted the take-off. He noted that the speed was 165 kt and the time was 35 mins passed the hour. The FO also confirmed that he assisted the Commander in applying the brakes to stop the aircraft but it failed to slow down.

Both FE confirmed that they did the external inspection separately and did not find anything unusual on the aircraft landing gears.

Both FE also confirmed that when the Commander aborted the take-off, the speed brakes and full thrust reversers were deployed and braking was effected. The FE noted that 4 anti skid lights were flickering for the Right Body Landing Gear and confirmed by the Check FE.

1.16.2 ATC Tower Controller.

The ATC Controller, who was on duty in the tower located approximately half way along the runway, reported that he heard a bang and noticed smoke coming from the aircraft as it passed in front of the tower and made a transmission to the crew to that effect.

1.17 Tests and Research

1.17.1 Company Rejected Take-Off Procedure.

The company reject take-off procedure is reflected in the Boeing 747 Operations Manual Volume 1.

The decision to reject a take-off according to the company rejected take-off procedure rests solely with the commander. The procedure stated that the decision must be made so stopping action can begin by V_1. If the commander

decided to reject the take-off, he/she should clearly announce "REJECT", commence the stopping action, and assume control of the aircraft. If the First Officer is making the take-off, he/she should not abandon control of the aircraft until the commander makes a positive input to the controls.

The procedure also stated that prior to 80 knots, the take-off should be rejected for system(s) failure(s), unusual noise or vibration, tyre failure, abnormally slow acceleration, engine failure, engine fire, unsafe take-off configuration warning; or if the aircraft is unsafe or unable to fly.

Above 80 knots, reject for engine failure, engine fire; or, if the aircraft is unsafe or unable to fly.

1.17.2 The Commander's Pre-Take-Off Briefing.

The following is a transcript of the commander's briefing taken from the aircraft CVR.

"This will be a flaps 10 noise abatement take-off, runway 30, its P1M, it says V_2 6 miles QP these two are in the box, climb 3000 to 7000, safe sector 2200 and transition altitude is 13000.

Any serious malfunction..set up is..(inaudible)..first outbound. Any serious malfunction before what (V_1) I call stop, standard means power idle, max reverse, speed brakes and max braking. You watch the speed brakes and when we come to stop, we..(inaudible)..emergency door on my command.

In case of engine failure..(inaudible)..1000 ft. level off,..(inaudible)..below 400 ft except..(inaudible)..and gear up, and we have to dump, 44 mins or we make an overweight landing, we decide later, any question?"

1.17.3 Take-Off N_1 and Speeds Computation.

The company procedures for calculating the take-off N_1 and speeds for the B747 for Runway 30 Sharjah International Airport requires the use of the Performance Manual Airport Analysis Handbook and Performance Data Sheets for the type of engines fitted where in this case, the CF6-50E2 engines. The take-off calculation and take-off bug card completed by the crew indicated entries of 33ºC for actual temperature and 10º flap setting.

The take-off calculation card indicated the maximum field limit of 378.9 tonnes and maximum climb limit of 405.5 tonnes. The assumed temperature obtained as indicated on the take-off calculation card was 46ºC.

The operator's B747 Operations Manual Volume 1 stated that when the actual weight is less than the performance limit weight at the actual temperature, the assumed temperature is obtained for the purpose of calculating take-off performance with reduced engine thrust.

The reduced engine thrust N_1 values for max take-off, go around and reduced were entered as 113.5, 113.5 and 109.0 respectively on the take-off bug card.

The take-off speeds obtained as indicated on the card are as follows; V_1 = 162 KIAS, V_R = 174 KIAS and V_2 = 180 KIAS.

The above take-off N_1 and speeds calculations were done in accordance with the company procedures.

1.17.4 No 9 Wheel Rim.

Laboratory analysis conducted by Honeywell ALS on the fractured wheel assembly, tyres and brake assembly fragments from the No 9 Wheel position produced the following test reports.

Visual examination of the wheel assembly showed the outboard wheel half was in one piece but had evidence of significant 'roll on rim' (Figure 1 of Appendix C). The wheel assembly was disassembled to allow a more complete inspection of the inboard wheel half. This inspection revealed the flange had fractured into three main pieces and several similar pieces (Figure 2 of Appendix C). It was noted that the c-flange areas of the inboard wheel had little evidence of any contact with the runway (Figure 3 of Appendix C).

Examination of the inboard wheel half also showed the main circumferential fracture had been badly damaged by post separation mechanical damage. Closer examination of the circumferential fracture showed all areas of the fracture had an angled nature which would not be typical of a fatigue crack. A further examination of the areas of the fracture that had not been completely obliterated identified a likely origin area (Figure 4 of Appendix C).

Unfortunately, due to the damage no fine fracture features could be observed. The axial location of the fracture at this point did not align with the end of the key boss cap. During the examination of the separated flange an area was noted that was consistent with damage created when the flange impacts the torque lug of the piston housing (Figure 5 of Appendix C).

Examination of the piston housing (PH) lug and attached section of brake rod showed the rod fractured about two thirds of the way to the opposite end (Figure 6 of Appendix C). Examination of the side of the piston housing lug that faced the wheel flange revealed damage typical of impact marks created by the wheel flange (Figure 7 of Appendix C). Inspection of the fracture surface on the torque lug showed features consistent with fast fracture (Figure 8 of Appendix C). No areas were detected that appeared to be due to fatigue crack.

Hardness and electrical conductivity of the wheel material, 137 HB_{500} and 38.2% IACS, revealed properties consistent with 2014 aluminium alloy in the –T6 condition.

Hardness and electrical conductivity of the piston housing material, 143 HB_{500} and 38.1% IACS, also revealed properties consistent with 2014 aluminium alloy in the –T6 condition.

Leak checks were performed on the inflation valve, over pressurisation valve and the fuse plugs. This check found no evidence of any leakage in any of the components when exposed to 200 psi pressure.

Following the results of the tests, Honeywell ALS concluded the following:

a) The overall shape and location of the fracture on the inboard wheel indicated the fracture mode was fast fracture and not fatigue. However, the root cause of the fracture of the inboard wheel was not determined.

b) The fracture surfaces on the wheel were badly damaged due to post separation mechanical damage making an exact fracture mode determination not possible.

c) The hardness and electrical conductivity indicated that the wheel and piston housing were the correct material and had been heat treated correctly.

1.17.5 Other Cases of Wheel Rim Failure.

1.17.5.1 Boeing reported a similar wheel fracture event which occurred on a B747-200 during take-off from Anchorage in 1995. Prior to the take-off, the flight crew reported seeing all main gear brakes 'steaming' and witnessed maintenance personnel pouring water directly on the Left Body Landing Gear. On the subsequent take-off, the No 8 wheel experienced a flange fracture that resulted in a 'trail of parts' being left on the runway. Included in those parts were wheel pieces, a fractured brake piston housing torque arm and torque rod/arm attached bolt. The same components were damaged and/or fractured and the debris pattern on the runway was similar to this accident.

1.17.5.2 Another incident involving the fracture of one of the inboard wheel on a B747-200 similar to this accident occurred on 14th December 2004 whilst the aircraft was taking-off from Incheon, South Korea. Post landing inspection of the aircraft revealed the forward right wheel assembly (No 6 wheel rim) of the Left Body Landing Gear had fractured and departed from the aircraft. However, the aircraft had took-off normally and only when the landing gear could not be retracted that the crew determined that there was something wrong about the aircraft landing gear system. The aircraft subsequently landed safely without further incident.

1.18 Organizational And Management Aspects

A review was conducted on the regulatory, operational and maintenance documentation provided by the operator. The operator had a valid Air Operator Certificate and there were no irregularities found in the aircraft documents issued by the Icelandic CAA. All required information for the safe conduct of the flight and the maintenance of B747-230C aircraft was current and available.

The Standard Practices Manual of the maintenance provider on cooling procedures of hot and overheated brakes allows the use of watermist as a medium in cooling hot and overheated brakes.

1.19 Useful or effective investigation techniques

Nil

2. ANALYSIS

2.1 Introduction

There was no evidence of any other systems malfunction or abnormality affecting the aircraft other than the failed No 9 wheel rim and associated components. From the FDR data, the failure of the No 9 wheel rim would not have been the main cause (s) of the accident, as the aircraft had already achieved V_1 and capable of taking off normally. This failure however, may reduce the effectiveness of the aircraft braking capability during the eventual aborted take-off.

The accident occurred as a consequence of an aborted take off, initiated by the commander, at a speed above V_1. It departed the paved surface and came to a stop about 30 metres from the runway end. Despite the claim made by the Commander that the abort was initiated around the V_1 speed of 162 KIAS, the FDR trace showed that aborting actions did not begin until 165 KIAS which was 3 kts above the V_1 speed. Furthermore, the aircraft continued to accelerate to 171 KIAS before decelerating and at this speed, the likelihood of the aircraft stopping within the accelerate stop distance available is practically negligible.

The decision by the commander to abort above V_1 played a significant role in the accident. It is obvious that this is a human factor issue involving decision making process. The analysis as to what prompted the commander to take such an action and other factors that had bearing to the cause (s) including flight crew operating technique and failure of the No 9 wheel rim are therefore discussed in the following paragraphs.

2.2 Flight crew operating technique.

There was no evidence to suggest that the company operating procedures were inadequate. The company reject take-off procedures dictates clearly when the decision to reject the take-off must be made and what actions are to be performed by each of the crew following a reject take-off.

The crew calculation of the take-off N_1 and speeds were correct and done in accordance with the company procedures. The eventual N_1 and speeds for the take-off were derived for a reduce engine thrust at the assumed temperature of 46ºC for runway 30, the runway in use at the airport with a runway length of 4220 m.

The commander perceived the take-off to have been normal until the call made by ATC informing them of “bang and smoke”. There were indications however, prior to that call that should have made it apparent to the crew that there was something amiss about the aircraft.

In fact, the thumping and flapping like noises as recorded by the CVR after the “80 knots” call made by the FO could have been observed by the commander that there was something wrong with the aircraft. However, he had dismissed the noises as “normal” and made the decision to abort only after the call made by ATC which coincided with the V_1 call made by the FO.

As a result, the stopping action was delayed until the aircraft speed reached 171 KIAS, 9 knots in excess of the V_1 speed of 162 KIAS and thereby did not meet the company reject take-off procedure that requires stopping action to begin by V_1.

Following the abort, the commander was able to maintain the aircraft on the runway centreline whilst attempting to stop the aircraft within the ASDA. However, when he perceived that the aircraft will not stop by the end of the runway, he decided to turn the aircraft to the left to avoid from hitting the runway approach lights.

2.3 Decision to abort.

The decision to abort by the commander is influenced by the following factors.

2.3.1 Impression of ‘fire’.

The ATC action to inform the crew that there was a bang and smoke was significant in triggering an abort response from the crew. As testified in his statements, the commander also believed that he heard the word ‘fire’.

Although the word 'fire' was not used by the ATC controller as confirmed by the CVR and ATC Tape Transcript, smoke is always taken as synonymous with fire. This would have created the impression by the commander that there was fire.

Fire is an emergency that demands immediate attention which is not accepted well among pilots. The decision whether to proceed or not when there is fire is debatable, as many would argue that it is better to be on the ground than to have fire in-flight.

2.3.2 Concorde Flashback.

Statement made by the commander indicated that he had a 'flash back' of the Concorde accident that happened in Paris on 25th July 2000. In that accident, the aircraft caught fire during the take-off. After take-off it lost control and crashed killing 109 on board.

The concord accident led the commander to believe that it would have been better to be on the ground than in the air. The commander's assumption on this event had a great influence to initiate aborting actions despite aircraft speed in excess of V_1.

2.3.3 Transmission Timing.

The transmission made by the ATC controller was intended to inform the crew that there was a bang and smoke from the aircraft. It was purely advisory as ATC is obliged to make an advisory call when it becomes apparent that the safe journey of the aircraft cannot be guaranteed. However, the transmitted timing coincided with the aircraft V_1 speed and the FO V_1 call. This information was confirmed by both the CVR and the flight crew statements.

Analysis on the length of the transmission showed that the ATC Controller took exactly 4 seconds to complete the call and by the time the abort was initiated, the aircraft had already achieved a speed of 165 KIAS. However, aborting action was done 3 sec after the start of the ATC transmission as was confirmed by the FDR/CVR trace.

2.4 Crew Briefing, Experience and Training

As a commander having in excess of 21,000 hours to his credit, his decision should be consistent with the actions as briefed during pre-flight and the company reject take-off procedures. The philosophy of V_1 cut forbids crew to abort take-off after this speed.

Though the Concorde accident was cited by the commander to justify his action, there were far more accidents and incidents resulting from aborting take-off above V_1. Despite what had happened during the Concorde accident, it is difficult to justify that this could be applied for all emergency situations of similar cases.

In this case, it would have been appropriate for the commander to continue with the take-off. Not only this action conformed to the operator's reject take-

off procedures and the associated training, the risks, in general, would have been far less as was the case in the Incheon incident in Korea, which experienced a wheel failure during take-off.

2.5 No 9 Wheel Rim Failure

2.5.1 The tests conducted on the failed wheel rim by Honeywell ALS concluded that the fracture was due to fast fracture and not fatigue as indicated by the angled nature of the fracture and the axial location of the circumferential fracture. The indicated chain of events as put forward by Honeywell ALS, could be described as follows:

1) the Inboard Wheel separates due to a fast fracture;
2) the separated flange impacts the PH lug;
3) the PH lug fractures and deflects the brake rod until it also fractures;
4) the outboard tyre fails; and
5) aircraft rolls on Outboard Wheel rim until coming to rest.

In the sequence of events, the outboard wheel rim (wheel No 9) would not have contacted the runway until the axle-mate tyre (wheel No 10) also deflated. Until that time, the No 10 tyre would have supported the front tyre. The limited damage on the Outside Diameter of the Inboard flange indicated that it most likely had already separated prior to the deflation of the tyre.

The corresponding marks on the Inboard flange and the PH lug suggested that the impact of the Inboard flange was responsible for the lug fracture. This fact coupled with the location of the PH lug very early in the debris field indicated that the Inboard Wheel fracture most likely was the initial malfunction. The axial location of the fracture and the angled nature of the separation indicated the fracture mode was fast fracture and not fatigue. There was no evidence detected on the wheel that would have accounted for why the component fractured by a fast fractured mode.

2.6 Compliance to Service Bulletin.

The Service Bulletin No 2607081-32-030 recommended that inboard wheels with Part Number 2607081-1/2 and manufacturing date through 1982 be retired during year 2000 or at the operator's earliest convenience. The IB wheel half of wheel No 9 was manufactured in August 1982 but was not retired and was overhauled for continued usage.

2.7 Procedures for Cooling of Brakes

There was also evidence to suggest that the maintenance procedures adopted by the maintenance provider may have contributed to the failed No 9 wheel rim. The Standard Practices Manual of the maintenance provider permitted the use of watermist for cooling of hot and overheated brakes. This method is used as the turnaround or ground time is too short for cooling down the brakes naturally or by the use of assembled cooling fans to the permitted maximum take-off temperature for the affected aircraft.

Using water to cool hot brakes may cause severe damage to the brakes and wheel rim. The use of this method may have subject the wheel and brake assemblies to thermal shocks and/or 'artificial' cooling of the thermal plugs integral to the wheel resulting in differential temperatures in the wheel assembly. The wheel may have then failed when exposed to the normal operating loads during the subsequent take-off roll.

3. CONCLUSIONS

3.1 Findings

(a) The aircraft was serviceable prior to the accident.

(b) The aircraft was correctly loaded and its documentation was in order.

(c) The flight crew were properly licensed, medically fit and adequately rested to conduct the flight.

(d) There was no evidence to suggest that the operator's operating procedures on Rejected Take-Offs was inadequate.

(e) The take-off N_1 and speeds were correct and done in accordance with company procedures.

(f) The take-off was aborted at a speed of 165 KIAS, 3 kt above the V_1 speed of 162 KIAS.

(g) The commander did not conform to the decision speed of V_1 when deciding to abort the take-off as prescribed by the operator's Reject Take-Off procedure in the operator's Aircraft Operations Manual Volume 1 for the Boeing 747 aircraft.

(h) The ATC transmission of 'bang and smoke' coincided with the V_1 call made by the FO.

(i) The ATC transmission to the crew was advisory and appropriate.

(j) The commander did not conform to the operator's rejected take-off procedures where the phraseology 'reject' should be clearly announced when the take-off was aborted.

(k) The crew was not aware that the No 9 wheel assembly had failed during the take-off roll.

(l) The Commander decided to abort the take-off after V_1 because he claimed that he believed he heard the word 'fire'. The word 'fire' was not used by the ATC controller when advising the crew of 'bang and smoke'.

(m) The No 9 wheel rim had suffered a sudden failure during the take-off roll which caused the IB wheel half to separate just inboard of the spokes.

(n) The Standard Practices Manual of the Line Maintenance Provider had allowed the use of watermist as a medium to cool hot or overheated brakes which may cause severe damage to wheel rims and brake.

(o) The Inboard Wheel half of the No 9 wheel assembly which carried a manufacturing date of August 1982 was not retired as recommended by

the manufacturer through Service Bulletin Number 2607081-32-030 Revision 3 dated 31st May 2001.

3.2 Cause

The cause of this accident was the termination of the take-off at a speed above V_1 with insufficient runway remaining to stop the aircraft safely as a result of the commander's interpretation that there was smoke and 'fire'.

3.3 Contributory Cause (s)

a) The failure of the No 9 wheel rim during the take-off roll which caused the bang and smoke.

b) The probable use of watermist as a medium to cool hot brakes which may have subject the wheel rims to fail under normal operating loads.

c) The continued usage of the inboard wheel half that should have been retired during year 2000.

4. RECOMMENDATIONS

4.1 The following are safety recommendations:

4.1.1 The State of Registry / Operator is recommended:

4.1.1.1 to re-examine the content of the operator's CRM courses to ensure the following subjects are adequately addressed;

4.1.1.1.1 decision analysis process at critical phases of flight;
4.1.1.1.2 mind perception;
4.1.1.1.3 lessons from past accidents/incidents.

4.1.1.2 to conduct further investigation as to the failure of incorporating Service Bulletin 2607081-32-030 Revision 3 dated 31st May 2001 by all concerned parties and to take the appropriate action.

4.1.1.3 to conduct a comprehensive investigation in respect to the repeated incidents involving the operator's B747-200 fleet undercarriage and wheels to determine whether there is any correlation.

4.1.1.4 to disseminate the appropriate information relating to this accident as much as possible for the purpose of preventing similar occurrences.

4.1.2 The State of Registry / Operator is recommended to ensure that the operator:

4.1.2.1 take the necessary steps to reemphasise in training that its cockpit crew respond to an emergency in accordance only with Standard Operating Procedures.

4.1.2.2 reviews the Standard Practices Procedures adopted by its line maintenance provider in the use of watermist to cool hot and overheated brakes.

4.1.2.3 urgently revises its procedures to ensure that all recommendations by the manufacturer issued through Service Bulletins are strictly complied.

4.1.3 The Airport Authority is recommended:

4.1.3.1 to ensure that the elevated approach lights and their supporting structures for the approach to Runway 12, which are located within the RESA for Runway 30 are made frangible in accordance with the requirements of Annex 14.

5. ATTACHMENTS

A - FDR GRAPHS

B - TAKE-OFF COMPARISON GRAPH

C - REPORT BY HONEYWELL ALS AND ANALYSIS

D - ATC TAPE TRANSCRIPT

E - TAKE-OFF PLOTS

F - DOCUMENTATION (GCAA use only)