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CIVIL AVIATION AUTHORITY, PAKISTAN
SAFETY & INVESTIGATION BOARD

SERIOUS INCIDENT: REJECT TAKE OFF PK-717 B-747 COMBI AP-BAK AT ISLAMABAD ON 21 JULY, 2003

Authority: Director General of Civil Aviation Authority
Memorandum # HQCAA/1901/286/SIB dated 21-07-03
Civil Aviation Authority, Pakistan

CONTENTS

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EXECUTIVE SUMMARY

Overview

1. On 20th July 2003, at 0347 local time, a Pakistan International Airline Boeing 747-240B AP-BAK (call Sign PK-717) aborted take-off and stopped at the end of the overrun. The aircraft had a total traffic load of 62,345 kg, 115,600 kg fuel and was departing from Islamabad to Manchester onwards to New York. The flight was a regular scheduled passenger / cargo flight with 270 persons aboard (254 passengers, 13 crew and 03 flight crew members). No person sustained injuries. The weather was clear with calm winds.

2. At approx 0342 the aircraft lined up on runway 30. The decision speed V1 was calculated by the crew as 149 knots. On achieving 80 knots, the flight engineer announced a problem in engine # 1. The Captain decided to continue, hoping for the engine to stabilize after obtaining some ram air. Just as the aircraft reached 100 knots, the flight engineer announced engine No. 2 problem and EGT overshoot on engine No.4 by 02 ^{O}C. By the time captain decided to abort and the thrust levers were moved back, the speed had reached 144 knots; brakes and thrust reverser were applied to stop the aircraft. The tires marking on the runway were from 7000 ft, leaving 4500 ft for the aircraft to come to a stop. The aircraft came to a stop on the overrun with nose wheel approximately 02 ft from RW edge. Due to heavy braking, the brake assemblies turned red hot, which increased the tire temperatures resulting in deflation of all 16 tires. All passenger and crew were disembarked in the normal way.

Nose Tyre approx 2 ft from end of the RW

All 16 Tyres deflated

3. The CAA fire crash tender arrived at 0352 hours and on the instruction of PIA engineering water was sprayed on the main landing gears. All tyres were changed on the overrun area. The Runway was cleared at about 2000 hrs and declared operational at 2100 Hrs. On 21st July 2003, after necessary inspections the aircraft operated a non-commercial flight to Karachi.

4. **CREW INFORMATION**

a. **PILOT-IN-COMMAND**

- ❖ Name: Tauqir Ahmed Sadiq
- ❖ Position in the Cockpit: Pilot In Command
- ❖ Date of Birth: 21-05-1948
- ❖ Type of Licence held and No: ATPL # 512
- ❖ Medical date with status: 19-02-2003
- ❖ Medical Certificate Standards: Class-I
- ❖ Rating:- Type (s) held: B707/720/747, Airbus A-310/300
- ❖ Type current: B747-100, 200 & 300
- ❖ Assist/Flight Instructor Rating: Nil
- ❖ Check Rating: Nil
- ❖ Flying Experience: -
  - Grand total: 17000 Hrs
  - Total in Command: 11000 Hrs
  - Total in command on the type: 1700 Hrs
- ❖ Accident / incident occurred: Engine Flame-out
- ❖ Where trained: Pakistan
- ❖ Date of joining the Organization: 26-07-1974
- ❖ Droop in Training Progress: A visible droop in A-310 flying was highlighted during his training sessions in Dec 1991. He had difficulties in FD, single engine and tackling wind sheer.

b. **FLIGHT ENGINEER:**

- ➢ Name: Mazhar Muhammad
- ➢ Position in the Cockpit: Flight Engineer
- ➢ Date of Birth: 23-11-1949
- ➢ Type of Licence and No: FEL # 133
- ➢ Medical date with status: 08-07-2003 Class-
- ➢ Medical date with status: 08-07-2003 Class-

- Rating: B707/720, A300, DC-10 & B747
- Type current: B747
- Flight Engineer Instructor: Check Rating
- Flying Experience:
  - Grand total: 15000 Hrs
  - On the type: 8000 Hrs
- Accident / incident: Nil
- Where trained: Pakistan
- Date of joining the Organization: August 1974

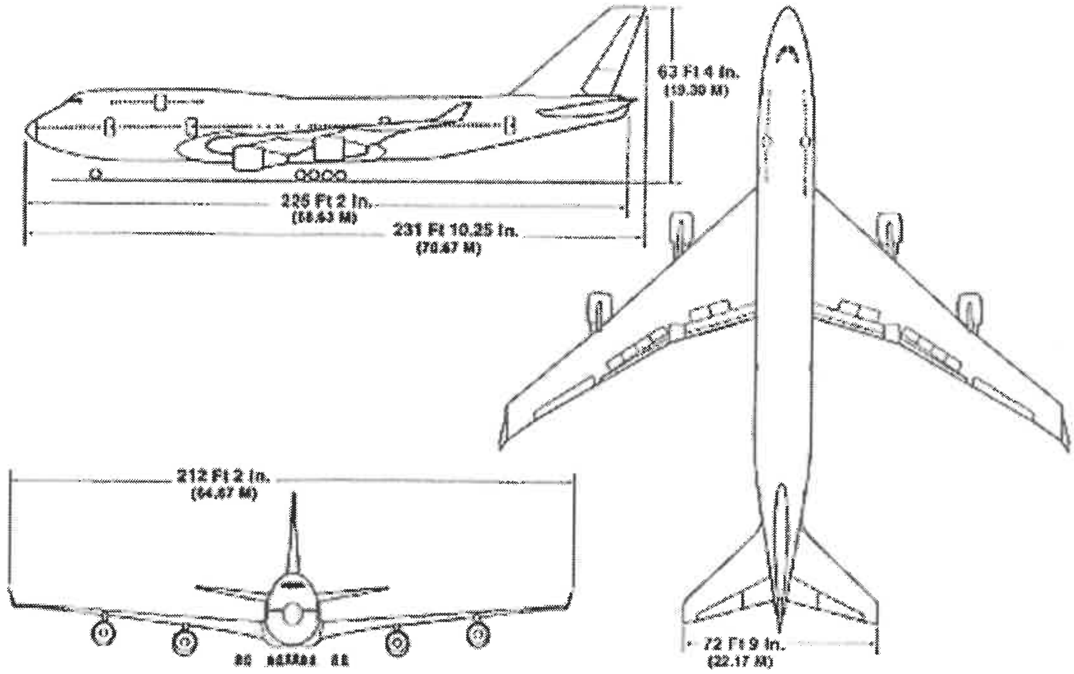
AIRCRAFT INFORMATION

5. This particular Boeing 747-240B was inducted in PIA on 30th July 1979. At the time of incident the aircraft had flown 76504 hours and 19977 landings. The aircraft has completed 100% design goal life and now on operating on enhanced airframe life. The aircraft is equipped with four CF6-50E2 engines with a thrust rating of 51800 pounds each.

- Aircraft type: Boeing 747-240B
- Registration Mark: AP-BAK
- Empty Weight of Aircraft: 158,382 kg
- Owner: M/s PIAC
- Air Operating Certificate No: AOC-003/96 AL dated 01.01.03
- Certificate of Registration No: 579
- Certificate of Airworthiness #/date of expiry: 532 / 24.06.2004
- Noise Certificate#: 01 dated 18th Nov 1996

6. **Aircraft Description:**

a. **Airframe** - The basic structure of the 747, except for size and weight, is similar to the structure design of the 707, 727 and 737 airplanes. The 747 is offered in three basic configurations; all passenger, mixed passenger/cargo, and all freighter. In convertible or freighter versions, the 747's volume and upward hinged nose allow straight in loading of long and bulky articles. An optional main deck cargo side door is available on all three models. An unusual feature of the 747 is the unique upper deck, immediately behind the cockpit. This area can be used as a luxurious first class lounge, or for standard passenger seating. The wing flap system, and a 16-wheel, four-main-truck landing gear allow the 747 to operate from any runways.



B-747-200B SPECIFICATIONS

- Span - 195 ft 8 in
- Length - 231 ft 10 in
- Tail Height - 63 ft 6 in
- Wing Area -. 5,500 sq ft
- Gross Weight - 775,000 - 833,000 lb
- Range - 6,000 nm
- Design Ceiling - 45,000 ft

- Power - GE CF6-50E2 (52,000 lb. thrust
- Typical Capacity - 270 passengers & Crew
- Fuel Volume - 52,409/53,985 US gal
- Airframe serial number: 21825
- Airframe flying Hours since New: 76504
- Airframe cycles / landings: 19977
- Year of Manufacture: July 1979
- Design Service Objective (DSO): 30,000 flight cycles or 115,000 FHS whichever occurs first

b. **Body** - The body is a semi-monocoque structure using circumferential frames at 20 inch (50.8 cm) intervals and longitudinal stringers.

c. **Wing** - The wing is a three spar box beam, with a mid-spar ending at the end rib of the outboard fuel tanks. There are no wing terminal fittings or pins for attachment.

d. **Empennage** - The vertical and horizontal stabilizers are of two spar box beam construction, and they have no terminal pins at their attach points. The vertical fin cannot be folded or laid down. The horizontal stabilizer is attached as a one piece assembly.

e. **Hydraulic brake system** - The 747 braking system is hydraulically powered from any one of three sources and is divided into a normal and reserve system. Both operate in conjunction with the anti-skid system for safe and efficient wheel braking under varying runway conditions. In addition, an auto brake system provides an automatic means of applying brake pressure and regulating airplane deceleration independent of the brake pedals pressure. The auto brake system operates only with the “normal” brake system.

f. **The Normal Brake System -** The normal brake system uses hydraulic system No.4 as a primary power source and hydraulic system No.1 as a secondary power source. Selection of hydraulic system No.4 or No.1 is made at the flight engineer's panel (P4). Positioning the NORMAL BRAKE SOURCE SELECT switch causes the motor-operated brake interconnect valve to port hydraulic pressure to the "normal" brake system from either system No.4 or No.1. When the auto brake system is not being used, two normal brake metering valves operated by the brake pedals provide pressure through a pair of shuttle valves to four normal anti-skid modules. Each module contains four control valves. The control valves receive pressure as necessary. The modulated brake pressure is then provided to individual wheel brake assemblies through shuttle valves. The shuttle valves block the "reserve" system when the normal brake system is functioning. The hydraulic system return flow from each of the four normal anti-skid modules is routed through the parking brake module. When the parking brake is set, the valve is closed. This stops the return flow from the anti-skid modules and allows the brake accumulator to provide parking brake pressure. During normal brake operation the parking brake valve must be open to allow return flow from the anti-skid valves.

g. **Anti-skid -** The anti-skid system prevents wheels skidding by limiting the hydraulic pressure applied to the brakes by the hydraulic brake system. Maximum braking efficiency is obtained when all wheels are in a slight skid. The system electronically controls an anti-skid control valve to continuously vary braking pressure in response to wheel action. Both normal and reserve brake systems are controlled by the anti-skid system. The normal system controls wheels individually; the reserve system controls wheels in pairs.

Each wheel rate of deceleration is compared with a synthesized rate of deceleration. Wheel decelerations within the airplane deceleration capability produce no correction signal. Wheel decelerations above this rate are treated as skids or approaching skids and correction signals are sent to the anti-skid control valve to reduce applied brake pressure. The correction signal is reduced when the wheel returns to speed again. The system continuously seeks a level of correction signals which produces slight skidding and thereby attains maximum braking efficiency. Maximum braking efficiency is obtained under any variety of runway conditions. The anti-skid system consists of an anti-skid control unit, a wheel speed transducer in each main wheel, and two anti-skid control unit modular assemblies (one normal and one reserve) for each main gear truck, a fault enunciator and a master anti-skid fault light at the pilot's P2 panel. The ANTI-SKID ON/OFF switch provides means of turning anti-skid system off during taxi and ground manoeuvres to eliminate possibility of low speed brake releases.

h. **Landing Gears -** The 747 nose gear consists of dual wheels located at station 395. The main gear is comprised of two body gears and two wing gears. Each main gear has a four-wheel truck. The body gear attaches to the fuselage at station 1463.5. The wing gear, which is forward of the body gear, is located aft of the rear wing spar at station 1342.5. The width between the body gear trucks is a distance of 12 feet, 6 inches. Distances of 36 feet separate the wing gear trucks.

i. **Brake Control System -** The captain's and first officer's brake pedals, which are conventional type rudder pedals, are interconnected through bus rods below the control cabin floor, to provide identical brake operation from both positions.

Cables connected to quadrants below the bus rods transmit brake pedal position to cable quadrants in each wing gear wheel well. The left hand brake pedals connect to the left hand wheel well, the right hand pedals to the right hand wheel well. The cable quadrants in the wheel wells are connected to an actuating lever by means of an adjustable rod. The actuating lever positions a plunger (slide) on the brake metering valves (normal and reserve) to govern the right and left normal and reserve braking pressure. The brake metering valves are located in the wing gear wheel wells (two in each). The upper valve in each wheel well is for the normal brake system (Hydraulic System #4 as primary, Hydraulic System #1 as secondary source). The lower metering valve is for the reserve system (Hydraulic System #2). The normal brake metering valves are set so that they will actuate slightly before the reserve brake metering valves. This is done by setting a closer gap between the actuating levers and the metering valve plunger.

7. **Aircraft Systems for Deceleration on Ground**

a. **Spoilers -** The primary role of the spoilers is to reduce wing lift and increase drag, thereby placing aircraft weight on to the tires. They should be deployed as soon as possible to minimize stopping distance. They are typically deployed automatically 3–5 seconds after reverse thrust are selected and in 1-2 seconds by a lever.

b. **Thrust reversers -** Reverse thrust provides a retardation force for stopping on ground by deflecting engine fan airflow forwards.

c. **Wheel brakes -** The brakes provide the primary means of stopping the aircraft, but their contribution to the total stopping force varies significantly with runway condition and groundspeed. The amount of braking force on the tire depends on the tire to runway surface friction and the weight on the wheel.

8. **ENGINE DETAILS.** The CF6 engine is a dual-rotor, axial-flow turbofan power-plant having a high bypass ratio. The 14-stage high pressure compressor is driven by a 2-stage high pressure turbine, and the integrated front fan and low pressure compressor is driven by a 4-stage low pressure turbine. Between compressor and turbine is an annular combustor. Reverse thrust is supplied by an integrated system which acts simultaneously on the fan and turbine exhaust streams.

9. **Engine Snag History.** Previously on 07th July 2003 while operating PK7192 at Karachi, the aircraft had aborted take-off at 100 knots due to engine No.1 delivering less take-off power. Similarly, on 09th July while operating PK787 at Karachi, the aircraft returned from take-off point due to engine No.1 delivering less take-off power. Details of the defect reported and rectification are as follows:

4th July 2003 - While operating PK 715, pilot reported No. 1 engine fuel condition actuator light blinks at times during flight.

6th July 2003 - While operating PK 788, pilot reported No.1 engine nacelle temperature higher. Loop 'A' remained slightly above 4 units and loop 'B' at 2.5. During climb loop 'A' rises to 6.0 and loop 'B' to 4.0.

7th July 2003 - While operating PK 7192, the pilot reported that when the take-off thrust was set to Max, the N1 reached to 109.5% whereas take-off thrust required for a temperature of 35 degree C was 112.5%. The take-off was aborted at 100 knots.

7th July 2003 - Engine No.1 Compressor Discharge Pressure (CDP) line was removed and the inline orifice was blown cleaned. Line was reinstalled. The safety details were carried out.

MPA test was carried out at OAT 36 degree C. The target N2 was 105.2% and target N1 was 103.6% with EGT 875 degree C. The recorded parameter of N1 was 104.3 with EGT 844 degree C. All parameters were found to be within limits and aircraft was released for flight.

8th July 2003 - The M.E.C (Main Engine Control) of engine No. 1 was replaced as preventive maintenance.

Note *- Certificate of Maintenance Review was issued on 02.07.03*

9th July 2003 - While operating PK 787, the pilot reported that No. 1 engine was unable to obtain take-off thrust with the thrust lever full forward. Target N1 was 113% whereas N1 obtained was 110%.

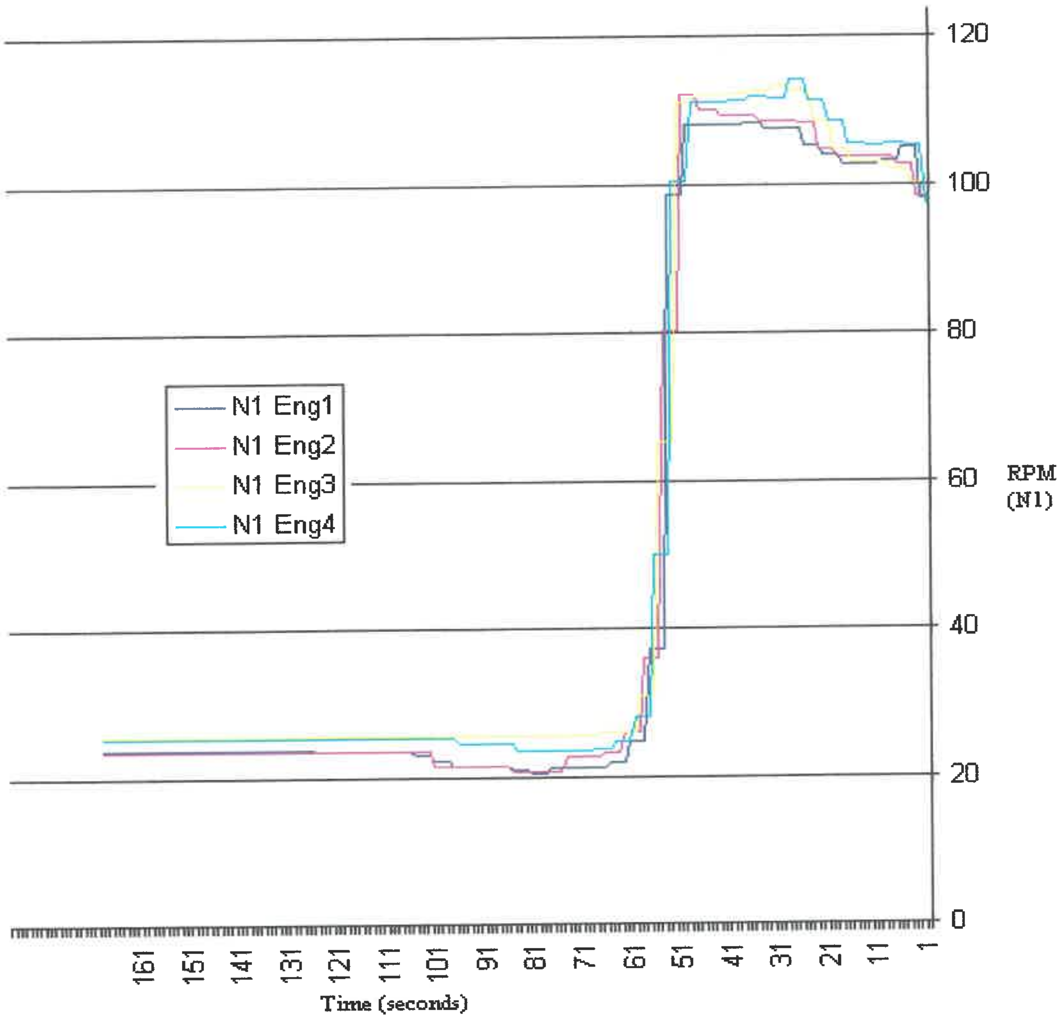
9th July 03 - While operating PK 788, pilot reported No.1 nacelle temperature ‘A’ loop shows in amber range 6.0 units during climb and 4.5 units in cruise and at low OAT (-40) and lower N1. Loop ‘B’ reads 2.5 units in cruise.

19th July 03 - While operating PK 717, the pilot reported No.1 engine parameters abnormal N1 107% and N2 109%. Required N1 was 113.8%. Engine No.2 failed to develop full take-off power and engine No. 4 EGT was 962 degree C approx at take-off power. Take-off was aborted at 140 KIAS (Approx). V1 was calculated as 149 KIAS with OAT 28 degree C at Alt Pressure of 2000 ft.

Note - On 13th, 15th and 16th July, three maximum power take-offs were conducted and all were satisfactory.

10. **Maintenance Records:** The lower check carried out on the aircraft was check 'A' which was performed on 30th June 2003 and the last major check was check 'C' which was carried out from 20th April 2003 to 22nd May 2003.

11. **Engine Trend Monitoring.** Two TSR were issued on engine No#1 explaining the trend and the health of the engines.

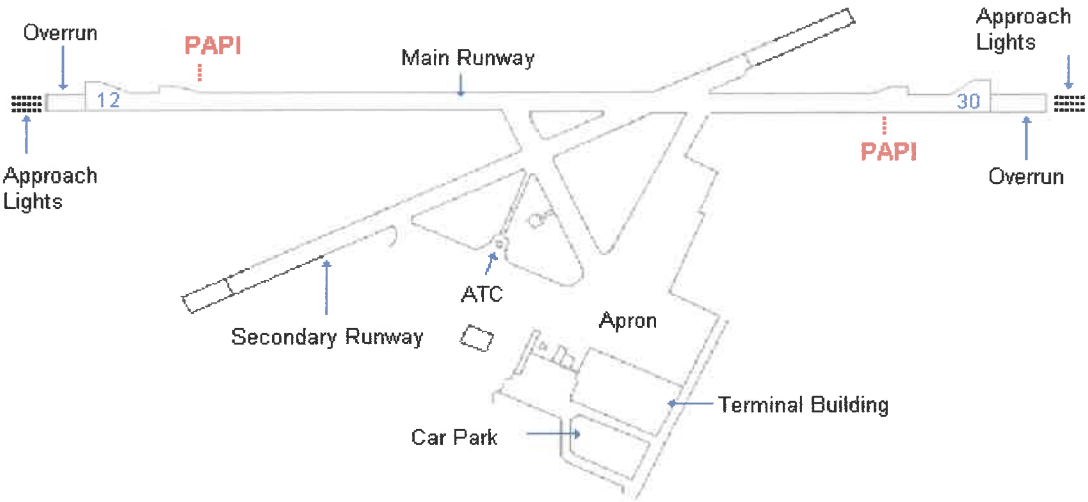


Engine types: CF6-50E2		
Engine serial#	Eng # 1(517-616)	Eng # 2 (455-381)
	Eng # 3(517-178)	Eng # 4 (455-334)
Engine hours:	Eng # 1 (348),	Eng # 2 (2126)
	Eng # 3(1331),	Eng #. 4 (1411)
Overhauls:	Eng # 1(52205),	Eng # 2 (56259)
	Eng # 3(56653),	Eng # 4 (58354)

Post Incident Ground Run Report is at Appendix 'A'

AERODROME INFORMATION

12. **Runway Information.** The Islamabad aerodrome elevation is 1660 ft above mean sea level. The main runway was constructed in the early 1960's. Runway 30 Accelerate Stop Distance Available (ASDA) is 11,500 ft and 150 ft wide. The overrun area for RW 30 is 500 ft and the length of the overrun for RW 12 is 750 ft. The main runway is bitumen surface and has a slope of 0.15% from runway 12 thresholds up to 5943 ft and a slope of 0.5% from runway 30 up to 2286 ft. Due to the age of the runway, regular maintenance is carried out. The CAA also carries out the runway surface friction reading which is available to the pilots.



Islamabad Airport Layout

13. **Airport Rescue and Fire Fighting Services.** The emergency crash bay is located at the middle of the RW and about 700 ft west of the runway. The team is equipped with 03 LCT, 01 Water Bowser and 03 Ambulances. The rescue team were informed by the ATC and reached the aircraft by 0410 hrs (After 8 minutes).

14. **Weather:** The weather was clear and wind was calm.

15. **Aids to Navigation/ Communications**. Aids to Navigation are non-factor in this incident. No communications difficulties were observed during the occurrence.

FLIGHT DATA RECORDERS

16. The aircraft is equipped with Digital Flight Data Recorder (DFDR), Cockpit Voice Recorder (CVR) and Performance Monitoring Recorder (PMR), The DFDR extract readout capability is available in PIA Engineering, and however, CVR and PMR extract readout is not available in the country. Therefore, CVR and PMR were sent to Honeywell Company, USA for readouts. The readout of PMR and CVR were received on 26 January, 2004, which resulted in delay in the finalization of the Investigation.

17. **Cockpit Voice Recorder.** The aircraft is equipped with Honeywell Cockpit Voice Recorder. It has three microphones recording i.e. one each for Captain, Co-Pilot and Flight Engineer. The system has 30 minutes recording and after 30 minutes another cycle of recording starts, which erases previous recording. Therefore, after an occurrence the CVR must be switched off by pulling out a circuit-breaker to preserve cockpit communication during the occurrence. Honeywell gave following report on the CVR recording.

a. Recording quality is very poor, with heavy background noise. Voices at times are unintelligible.

b. No voice recording from Co Pilot's microphone.

c. For preserving the original recording information no filters were applied for noise suppression.

18. The CVR transcript received on normal audio cassette has the above mentioned discrepancies. In addition, the Cockpit Crew did not pull out the CVR circuit breaker, which resulted in erasing of Cockpit conversation during the event. As long as the aircraft power supply was on, the CVR continued rewinding and erasing previous conversation. The recording received on the cassette is the conversation on Flight Deck about 25-30 minutes after the completion of Reject Take Off. This recorded discussion among Captain and Flight Engineer is about analysis of engines' performance leading to RTO and these are the basis for snag entries on Tech Log Book of the aircraft. The CAA Rules and FOM do not recommend circuit-breaker pull-out, however, an OETB issued by Chief Pilot Technical dated 22 February, 1999 directs such action mandatory and its inclusion in FOM.

19. **Performance Monitoring Recorder (PMR).** Performance Monitoring Recorder gives details on engine parameters, Reverse Thrust, Speed brakes and throttle quadrant. The PMR is also a Honeywell Product. On this aircraft the throttle lever angle vis-à-vis N_1 and N_2 RPM, EGT readings, use of Reverse Thrust and extension of speed brakes can be established. Though, N1 RPM and Reverse Thrusts are available on DFDR also. The vendor's report (Appendix 'B') describes non availability of data on PMR recording i.e. unserviceable PMR.

20. **Digital Flight Data Recorder (DFDR).** The aircraft is equipped with DFDR and data can be down loaded in graphical and numerical form locally. It gives all flight parameters (Appendix C') and salient engine parameter readings on a second to second basis. The speed of the aircraft is available after 50 kts CAS. However, the heading change and acceleration Gs in three planes helped in establishing brake release on start of take off and the

time when aircraft came to a halt after rejecting take off. Hence the time of acceleration and decelerations to a stop were available on readouts. The results of engine handling on N1 and fuel flow are also available along with application of Reverse Thrusts. These parameters are adequate to determine cockpit crew action on take off acceleration and RTO sequence. These parameters also help in establishing the RW consumed on acceleration and RTO.

21. **<u>ATC Tape Extracts</u>** ATC tape extract were analysed, which reflected nothing that could add to the evidence. It included normal R/T communication for taxi/take off only and post incident communication e.g. Crash Fire Tenders reaching on the scene, arrival of Engineering Staff and disembarkation etc. ATC recording also helped in establishing the time frame of available CVR recording, which is 25-30 minutes after the aircraft came to a stop.

22. HISTORY OF FLIGHT

On 20th July 2003, the aircraft arrived from Karachi without encountering any technical problems related to the engines. On arrival at Islamabad, the concerned AMEs carried out the transit check and issued the Maintenance Release. As per ground engineers statement the crew did not discuss the engine history. The defect that was enquired by the Flight Engineer was regarding the pressurization 'Auto Mode' functions. The crew calculated the decision V1 speed as 149 knots. At 2242:30 UTC the aircraft lined up at runway 30 for take-off. The throttles were moved forward at 2244:46 and brakes were held for 30 second. On achieving approximately 98 % N1 on all engines, the brakes were released. The Captain aborted take-off at 144 knots.

WEIGHT AND BALANCE

23. The aircraft was last weighed on 18th June 2003. The aircraft has an empty weight of 158,382 kg. The maximum brake release

weight (Structural Limit) given in the weight schedule is 362,873 kg. On every flight, a load sheet is prepared by a licensed traffic officer. This load sheet is checked by the Flight Engineer and then signed by the Captain. On this flight, the load sheet was prepared by traffic officer who was holding a valid Mass and Balance Control Licence (No. 3341) issued by PIAC. Since the flight commenced its journey from Karachi therefore, maximum of it cargo was in transit. The weights are given to the trimmer who enters it in a computer. The calculations are carried out by a computer based software and the load sheet is printed (Appendix 'D'). In case of an error, the computer identifies it and does not print the load sheet. The figures given to the trimmer for this flight are as follows:

		Weights (kgs)	
a.	Compartment Load	44448	
b.	Pax / Cabin Bag	17830	
c.	Traffic load (a + b)	62345	
d.	Dry operating wt	177830	Given by the manufacturer for each aircraft
e.	Zero fuel wt (c + d)	240175	247207 (Max allowed)
f.	Take-off fuel	115600	
g.	Take-off wt (e + f)	355775	356800 (Max allowed)
h.	Landing wt (g – f)	256275	265351 (Max allowed)
j.	Taxi out fuel	800	
k.	Take-off wt after taxiing (g – j)	354975	356800 (Max allowed). Leaving a margin of 1825 kg. With 114800 kg of fuel (115600 – 800 = 114800)

Table 1

24. **Fuel Indent & Load Instructions**

The Fuel Indent sheet is prepared by the aircraft ground engineer. In this sheet, the quantity of the fuel at the time of arrival and the fuel that is uplifted is given. As per fuel indent, the following figures were given:

		Weight (kgs)	
a.	Fuel in the tanks	25800	
b.	Fuel uplifted lsbd	91458	
	Total fuel onboard	117258	
	Taxi out fuel -	800	
	Fuel at take-off	116458	
	Fuel in the load sheet	114800	(Refer Table 1 column 'I')
	Difference between fuel onboard and fuel for calculating CG	**1658**	

Table 2

25. **Difference in Fuel Calculations.** By adding the weight of the fuel i.e. 1658 kg, to the Aircraft Take-off weight mentioned in the load sheet, the margin between the actual take-off weight and max allowed take-off weight reduces (Refer Table 3 below). A margin of only 167 kg is left. With this less margin, which is detected, there are possibilities that extra non-recorded weight maybe put on the aircraft and the take-off weight might have been more than the limit weight. This also indicates a lack of communication and coordination between the Traffic department, Flight operations and Engineering.

		Weights (kgs)	
a.	Load in Compartment	44448	
b.	Passenger / Cabin Bag	17830	
c.	Total traffic load (a + b)	62345	
d.	Dry operating wt	177830	Given by the manufacturer for each aircraft
e.	Zero fuel wt actual (c + d)	240175	247207 (Max allowed)
f.	Take-off fuel	115600	
g.	Take-off wt actual (e + f)	355775	356800 (Max allowed)
h.	Landing wt actual (g – f)	256275	265351 (Max allowed)
j.	Taxi out fuel	800	
k.	Take-off wt after	354975	356800 (Max allowed).

	taxiing (g – j)		**Leaving a margin of 1825 kg.** With 114800 kg of fuel (115600 – 800 = 114800)
	Diff between actual fuel onboard and fuel used for calculating the CG of the a/c (Table 2)	1658	
		356633	**356800 (Max allowed)**
	Margin left:	167 kg	

Table 3

26. **Damage Report.** There was no damage to the aircraft in the incident except all 16 tyres deflated after the incident due to safety design feature. The Boeing 747-240B has 16 main landing gear wheels and two nose landing gear wheels. All tyres are inflated with nitrogen and are installed with fusible plugs. By applying excessive brakes, the temperatures on all the main tyres increased, due to which the plugs melted. The nitrogen gas is then released into the atmosphere. The tyre markings started at approx 7,000 ft (4,000 ft to go).

REJECT TAKE OFF THEORETICAL FRAMEWORK

27. Rejected takeoff (RTO) accidents have been and continue to be a significant contributor to worldwide commercial aviation statistics. The National Transportation Safety Board (NTSB) has highlighted two basic reasons for RTO accidents and incidents and "suggests that pilots faced with unusual or unique situations may perform high-speed RTO's unnecessarily or may perform them improperly". Available data indicates that over 75% of all RTO's are initiated at speeds of 80 knots or less. These RTO's almost never result in an accident. The overrun accidents and incidents that do occur are approximately 2% of all high speed RTOs. Fifty-eight percent of all high speed RTOs were initiated at speeds in excess of V_1. Analysis of the available data suggests that approximately 80% were avoidable. In addition, it is important to note that in 75% of all RTO accident cases full takeoff power was available.

28. These potentially avoidable accidents can be divided into three categories. Roughly 9% of the RTO accidents were the result of improper preflight planning. Some were caused by loading errors and others by incorrect preflight procedures. About 16% were result of incorrect pilot technique/ procedures. These were caused due to delayed application of brakes, failure to deploy the speed brakes, and the failure to make a maximum effort stop. What should all these statistics tell? First, RTO's are not a very common event, second and more important, the infrequency of RTO occurrence may lead to complacency. Every pilot must be prepared to make the correct "Go/No Go" decision on every takeoff. Following parameters highlight better GO/NO GO decisions:

29. **V1 Criteria** – "V_1 is the maximum speed at which the rejected take off manoeuvre can be initiated and the airplane stopped within the remaining field length". Second, with respect to Field Length

Limit Weight "GO" criteria, V_1 is also the earliest point from which an engine out takeoff can be continued and the airplane attain a height of 35 feet at the end of the runway.

30. **Engine-Out Accelerate-Stop Distance**. This is the distance required to accelerate with all engines operating to the engine failure speed V_{EF}, have an engine fail at least one second before V1, recognize the failure, reconfigure for stopping and bring the airplane to a stop using maximum wheel braking with the speed brakes extended. Reverse thrust is not used in the FAR distance calculation.

31. **Field Length Limit Weight Take off**. For a given length runway, if the actual weight of the airplane is equal to the limiting weight, as determined by any of the above criteria, the takeoff is described as being at a Field length Limit Weight.

32. **RTO Actions.** From the certification flight testing, the average demonstrated time for the test pilot to apply maximum braking, bring the thrust levers to idle and raise the speed brakes is about one second. The line pilot does not know when or if a reject will occur, so an additional two second distance allowance is added. This allowance is provided to give the line pilot adequate distance to get the airplane into the full stopping configuration. "Prompt" accomplishment of the RTO procedure can represent a stopping distance advantage over the calculated distance of up to 600 feet. It is not there to give additional time for the Go/No Go decision.

33. **Balance Field Limit Weight**. The intersection of the "REJECTED TAKEOFF" and the "CONTINUED TAKEOFF" lines define the maximum airplane weight that will satisfy both of the engine-out criteria. If this weight is less than the all-engine Field Length Limit Weight, it then becomes the limiting weight for the takeoff. The takeoff is then described as being at a "Balanced Field

Limit Weight" because the "GO" and "STOP" distances are equal. It is characterized by the fact that the airplane will require the entire runway length to reach 35 ft or to stop, if an engine fails at V_{EF} and the RTO is initiated at V_1. Therefore, if a higher speed is chosen for V_1, the weight of the airplane must be restricted to enable the stop to be completed within the available runway. Conversely, if the V_1 speed is low, the airplane can weigh more and still stop on the runway. The trade between V_1 and allowable takeoff weight is exactly the opposite for the "GO" case. If a low value of V_1 is chosen, the airplane will need to be at a lower weight in order to accelerate to flying speed with one engine failed. If a higher value of V_1 is chosen, the airplane weight can be increased because all engines are operating for more takeoff run. It is important to note that at a Field Length Limit Weight; approximately 60% of the runway is consumed to accelerate to V1 and there is as little as 40% runway available to either STOP or GO from V_1.

34. **An Engine Out Go Decision.** Consider a one-engine-inoperative case where the engine failure occurs more than the prescribed one second before V_1. A typical range of accelerations for jet transports is 3 to 6 knots per second when near V_1, As shown in the figure (Appendix 'E'), a "Go" decision made with the engine failure occurring two seconds prior to V_1, will result in a screen height of 15 to 30 ft. for a Field Length Limit Weight takeoff instead of 35 feet. While for a four engine airplane 2 Sec before V_1 and @ 4 kts/sec^2 acceleration, V_{EF} would give 20 ft height at the end of the runway.

35. **Speed Brake & Wheel Braking Performance.** The speed brakes add to aerodynamic drag and the effectiveness of wheel brakes increases as the aircraft weight is quickly transferred on the wheels due to reduction in wing lift. The speed brakes increase the total drag by 70% to 100%. With the speed brakes up, the total high speed stopping force that can be generated is 30%-50% more than

the stopping capability with the Wheel Brake only (for takeoff flap settings). At low speeds the speed brakes are less effective and thus have a lesser impact on stopping performance on low speed RTO. On a dry runway, raising the speed brakes 5 seconds late during the RTO will increase the stopping distance by nearly 300ft. Not raising the speed brakes will extend the stopping distance by up to 600 feet, or result in an overrun speed of up to 70 knots.

36. **Speed brakes vs. Reverse Thrust.** The rejected takeoff certification testing under FAA rules does not include the use of reverse thrust. As a result, an additional stopping margin is produced by using maximum reverse thrust. On a dry runway, failure to raise the speed brakes will result in a substantial overrun, even if maximum engine-out reverse thrust is used.

37. **RTO Preparedness.** A decision of RTO is made not at the time of rejection. The critical decision is made in the crew briefing in line with SOPs. A successful RTO decision and correct actions stem from a clear and concise briefing at flight deck by the Captain. Good preflight preparation to include:

- Use of standard callouts during the takeoff.
- Positive pre-considered action if a malfunction occurs.
- No doubt in any crew's mind about his role in takeoff.

38. During takeoff, callouts fall into three general categories. Those normally made prior to V_1, malfunctions, and the V_1 callout itself. Thirdly, as recommended by the NTSB, to clearly announce when entering the company-defined "high speed" regime. In the low speed regime it's reasonable to reject for:

- System Failures
- Unusual Noise or Vibration
- Tire Failures
- Abnormally Slow Acceleration

- Unsafe Takeoff Configuration Warning
- Engine Failure or Fire
- The Airplane is Unsafe or Unable to Fly

However in the high speed regime, it's recommended to reject only for the most critical items:

- Engine Failure or Fire, or
- Airplane is Unsafe or Unable to Fly.

39. **<u>Communication and RTO Decision</u>**. The communication regarding an abnormal situation during takeoff can mean the difference between success and disaster. Therefore, communications must be precise, effective and efficient. Standard callouts contribute to situation awareness. The callouts, coupled with both crew members monitoring airspeed, leave the crew with a common perception of what actions are proper in the event of an-abnormal indication. The crew member noting a problem should communicate this clearly and precisely without inferring things that may not be true. The RTO decision should be clearly announced using the standard airline words. The crew must be prepared to make the Go/No Go decision on every takeoff. If a "No Go" decision is made, the crew must quickly use all of the stopping capability available. Too often, the records show, uncertainty in the decision process and a lack of completeness in the procedures result into RTO accidents and incidents.

<u>EVIDENCE</u>

40. **Engine Snag History.** The aircraft maintenance aspects in detail have been covered in Technical Report. From operational point of view following points merit discussion:

a. In last thirty days aircraft rejected take off twice due to less than target N_1 on Engine # 1. Both the times necessary rectification was carried out by maintenance and aircraft was cleared for flying. The problem was sighted when N_1 requirement was higher and N_1 could reach up to 110% only, however in this incident the N_1 remained at 107% till 80 kts and then crept up gradually to 108% till 144 kts. In post incident ground run by maintenance personnel, the snag was repeated. In earlier case take off was rejected at 100 kts, though, aircraft had achieved full power take off thrice during same period.

b. The Engine # 2 also had a similar snag reported by the same Captain i.e. Captain of the RTO incident. The N_1 did not meet target of 112% and remained at 111%, yet, the take off was continued. During the incident of RTO N_1 was 108% at 80 kts and it gradually increased to 112% at 144 kts when take off was rejected. In the former case the rectification was undertaken as per AMM 72-00-00.

c. The Engine # 4 EGT Excursion at full throttle take off was recorded at 965^{0}C, by same Captain on 27 June, 2003, which was controlled by throttle retardation. In this incident EGT Excursion was 962^{0}C and it appears on DFDR that effort was made to control EGT by throttling back. In the first case no rectification was carried out because when EGT excursion was checked it was found within limits.

d. After the incident no other snag was recorded on any other system malfunction except "all tyres deflated".

e. There were records in "Take off Power Performa" related to EGT excursions or history of full power take offs Appendix 'F'.

f. The ground engineers used water for cooling the hot brakes, which resulted in quenching and caused jamming of brake assemblies.

41. **Flight Deck Procedures**. In the interview PIC asserted that routine procedures are spelled out on memory, however, whenever a question was asked about specific checks he referred to SOPs/Checklist and declined to give steps. His statements on personally checking the tech log history are also conflicting. Though, Flight Engineer and First Officer showed clarity and were specific about answers to questions, both are in agreement that Tech Log Snag history briefing was covered by FE. In the briefing FE covered the problem on Engine # 1 not reaching target N_1 twice during take off and resulting in low speed RTOs. It may be noted that RTO is not a routine event in wide body aircraft; therefore, any RTO incident gets wider coverage especially if it happens on the same aircraft twice in quick succession. Such incident should alarm flight deck crew and that would lead to being more comprehensive on their routine checks and briefing. PIC had experienced lower than target take off N_1 on Engine # 2 and EGT over boost to 965^0C (instead of 960°C) but he decided to continue the take off on 27 June, 2003 on the same aircraft. This knowledge on the technical history of the aircraft called for harnessing all procedures and doing those religiously, especial when operating on MTOGW in dark hours. The PIC gave, once again, conflicting statements regarding conduct of "Crew Briefing". Later, he was in conformity with FE and FO on conduct of "Crew Briefing". PIC used his discretion and judgment for not covering the same in spite of having a new set of flight crew on this sector. The Boeing Company's assertion on RTO and Airmanship dictates that correct decision of RTO and accomplishment of timely RTO actions can be ensured by conducting a comprehensive "Crew Briefing". The "SOPs" do cover this aspect adequately, however, last sentences on the subject Para empowers Captain of B-747 to use his judgment and simply

say "Standard Crew Briefing" as it was done in this particular case by Captain of PK-717 on 20 July, 2003 at Islamabad. However, crew briefing as given in B-747 SOPs (May 2000) bounds PIC to conduct RTO procedure specific to Co-pilot and Flight Engineer actions up to 80 kts and V_1 to preclude any ambiguity

42. **Take off Data.** Take off data was calculated correctly for the given weight on load sheet, Accelerate Stop Distance Available (ASDA) at Islamabad runway and prevailing atmospheric condition at that time i.e. 28^0C and 1000 mb. The runway surface was dry and within surface friction limits, while wind was light and variable. The Flaps were selected 20^0 and target N_1 was calculated to be 113.8%, which was with thrust levers at maximum forward mechanical stop position for given QNH and temperature. The QNH setting increased corrected elevation, from 1662' AMSL to 2000' AMSL and corrected runway length was 12000'. The calculated V_1 from charts was 154 kts and 5 kts less (149 kts) was selected as a datum for initiation of RTO. The manufacturer gives 3 to 6 kts/sec acceleration near V_1 depending on the weight of the aircraft. In this particular case the acceleration near V_1 was 03 kts/sec as it was a maximum take off gross weight. The airline policy dictates subtraction of 5 kts from actual V_1 to give line pilot one second so as to accomplish RTO actions by V_1 and not for decision making. For this set of conditions the 5 kts less than V_1 datum meant almost 02 seconds. Therefore, in a similar situation Flight Crew may choose to continue take off at $V_1 = V_{EF}$ i.e. two seconds before actual V_1. It may be noted that manufacturer's charts cater for three seconds in accomplishment of RTO actions at V_1 by line pilots. It also implies that if line pilot completes RTO actions in one second like test pilots do in trial/evaluation, he would have the advantage of additional 600 feet in stopping the aircraft at V_1.

Cockpit Crew Actions

43. **Take Off Roll**. The following communication and actions took place on PK-717 during take off roll when engines' parameters were found to be out of limit:

- Co-pilot call-out: 80 kts.
- Flight Engineer call-out: Take off power on Engine #1 has not developed and there is a parameters mismatch, N_2 has gone to the limit. (In vernaculars)
- Captain monitored the Engine Instruments for few seconds
- Captain call-out: With ram Air N_1 will increase.
- Flight Engineer call-out: Engine # 2 thrust lever has gone to mechanical stop and not giving more than 109% N_1, and Engine # 4 EGT is beyond limits.
- Captain assessed the situation for few seconds and aborted take off without announcing his decision after rolling for 23 seconds since 80 kts and total take off roll of 49 seconds.

44. **Abort Actions.** Following is the RTO sequence:

- Thrust Levers retarded at 144 kts and simultaneously Wheel Brakes applied
- Reverse thrust applied without increase in N_1 after about 8 seconds at 101 kts.
- Speed brakes extended in auto function with reverse thrust interlock selection at 101 kts or about 08 seconds after initiation of abort actions.
- The aircraft came to halt with nose wheel less than two ft from the end of Accelerate and Stop Distance Available (ASDA)
- Aircraft stopped in 39 seconds from 144 kts

45. **Decision Making.** The leadership of the Captain on the flight deck is an established order; however, the inputs from other flight deck crew clearly help in making timely and correct decisions. The airline policy and training practices, it seems, emphasis on following ones domain only, inline with checklist/Flight Crew Manual/SOPs steps and call outs. These set of conditions create an environment where Captain is bound to make decisions based on his understanding only and he cannot benefit from the knowledge and experience of other Flight Deck Crew members or take any assistance unless asked for. In RTO time is a crucial factor and FO/FE ought to supplement Captain as clearly highlighted in FOM. Similarly in a situation where an unusual situation arises, a case of compound system malfunction or a scenario on which guidelines/steps are vague in procedure would invariable result in communication gap leading to inadequacies in decision making process. The situation gets worse if knowledge of the decision maker is not adequate. The adequacy of training and knowledge is manifested in consistency in decisions and following procedures.

Weight And Balance

46 The aircraft was carrying full load of passengers with their baggage on departure from Islamabad. In addition, about 27 tonnes perishable cargo was loaded from Karachi for Manchester. The aircraft was carrying a total 44.49 tonnes load and 115.6 tonnes fuel.

a. **Passenger Load**. There were a total of 254 passengers and 16 operating / rest non revenue persons on board. This includes 111 passengers from Karachi comprising 87 adult, 9 children and 05 infants. At Islamabad, 223 Adults, 19 Children and 05 infants were on board. Two passengers joined later. The weight of the passenger and their hand carried baggage was calculated @ 75kg per adult, @ 37kg per child and @ 15

Kg for infant according to international Standards. However, this calculation does not cater for heavier hand baggage carried by individual. In addition, the load sheets comparison Ex Karachi and Ex Islamabad show variation in number of passengers as passed by traffic, where 15 adults have been replaced with 15 children and 03 infants added.

b. **<u>Passenger Baggage</u>**. Total passenger baggage shown in the load sheet is 15.22 Tonnes at Islamabad. This includes 5.7 Tonnes Ex-Karachi. The manifest details provided number of passengers and gave the exact baggage weight carried by each passenger Ex-Karachi. The sum of individual baggage weight is 5 tonnes on manifest; however, assessment weight entered in the load sheet is 0.7 tonnes more. The USA bound passengers are authorized 64 Kg per Adult/Child and the average baggage weight is 60 Kg/passenger, though, it includes 21 passengers for Manchester who were authorized @ 30 Kg only.

c. A total of 153 passengers boarded from Islamabad and all were USA bound. Ex-Islamabad passenger baggage load is shown 9.5 tonnes, an average of 62 Kg passenger, as if all carried their entitled weight. The entire baggage was weighed after the incident, which was 13 tonnes only i.e. 2.2 tonnes less than the Trim Sheet weight. It is evident from load sheet that 9.5 Tonnes personal baggage was checked in for 151 JFK passengers in Economy class. However, check in counter baggage list shows 242 pieces and 6 tonnes i.e. 3.5 tonnes less than registered in load sheet. Though, when weighed after the incident, it was 2 tonnes less than load sheet weight. These figures suggest that personal baggage on load sheet is an assessment towards positive and caters well for extra hand carried/un-accounted excess baggage. This may also be taken as inaccuracies in load sheet preparations.

d. **Cargo Load.** Bulk Cargo of 26.6 tonnes, which were mango crates, was loaded at Karachi. In addition, 139 Kg small revenue / mail cargo was also loaded at Karachi. At Islamabad 650 Kg US mail cargo was added. After the incident, the cargo was weighed again for verification. The surplus difference is about 500 Kg in seven Pallets of mangoes loaded at Karachi.

e. **Fuel.** The fuel calculations given at Part 7 indicates that fuel carried was actually 1.6 tonnes more than the fuel specified in the load sheet.

f. **Balance.** The passengers' baggage which constitutes about 33% of the entire cabin / cargo load shows clear discrepancies in baggage weight calculations up to 25% discrepancy over entire cabin/cargo/fuel weight. These discrepancies would always be translated into incorrect balance. Though, in this case weight shown on load sheet is more than actual weight, yet, the aircraft's balance would be affected. Further more, as the load could not be weighed by the investigation team, the task was entrusted with the same set of people who weigh and prepare the load sheet. Therefore, so many variations in passenger baggage weight clearly indicate the weakness in the system and pilot may not know the actual weight of the aircraft.

OPERATIONS' ANALYSIS

47. The operational analysis shall discuss the deviation from SOPs and Fight Manual, if any, and establish the aircraft performance vis-à-vis flight crew actions, including discussion on the team work at flight deck. The basis of analysis is DFDR readouts and Flight Crew's statements. The same has been compared with a study by Boeing Company as given in the theoretical framework.

48. **Accelerate Stop Distance Available (ASDA).** All aircraft have to back-track at Islamabad runway 30 and execute a turnabout to line up. The turn about always results in straightening of the aircraft while coming on the center line, this invariably leaves at least an aircraft length of runway un-utilized, especially, while executing a static take off. The Accelerate Stop Distance Available (ASDA) for Islamabad runway 30 is 11500' when fighter aircraft arrester barrier is not installed for runway 12. Therefore, it is evident that ASDA for runway 30 reduces by about 200 feet due to back track and turn-about for Boeing-747.

49. **Engine Run-up** PIC chose to perform static take off due to MTOGW. The engines were run up at 97-98% N_1, except Engine # 3 at 92%. The split on Engine # 3 is not understood as it could be matched with the rest. However, the company and the manufacturer recommended normal T/O engine run up at maximum 70% N_1 due to following reasons:

a. Above 70% N_1 chances of FOD pick up are more.

b. Above 70% N_1 engine spool up is rapid.

c. There is less split in N_1 between engines.

d. There is an increase in noise pollution above 70% N_1.

50. It is important to note that at 97% N_1, the engines achieve 95% take off thrust. Furthermore, N_1 spool up to 95% is achieved in maximum 08 seconds from flight Idle. As engines' malfunctions occurred above 97% N_1, therefore, it can be concluded with certainty that engines spool-up had not influenced the events that followed later. Additionally, at least two engines were giving requisite thrust (# 3 & 4) and remaining two engines (# 1 & 2) were producing more than 95% thrust.

51. **Takeoff Roll** At the time of brake release Engine # 3 N_1 was at 100%, though its acceleration to target N_1 lagged but rose steadily. The aircraft took 26 seconds to accelerate to 80 kts. It was only Engine # 4 that reached target N_1 (113.8%) that too only one second before 80 kts. While Engine # 3 got target N_1 two seconds after achieving 80 kts. The N_1 on Engine # 1 and 2 was 107% and 108% respectively at 80 kts i.e. 5-6% less than target N_1. Keeping in view that aircraft took 26 seconds to reach 80 kts and engine acceleration is rapid above 70% N_1 and even quicker near or above 95%, yet, all four engines could not reach target N_1 from 98% in 26 seconds. It can be attributed to poor engine performance or very slow thrust lever push forward. The possibility of FE's thrust levers' movement from 98% to 113% N_1 in 25 seconds is ruled out as he had already announced the problem right after 80 Kts and it did not increase to required N_1 till RTO. The SOPs and Ops Manual give 80 kts datum for selection of target N_1 by FE and if not achieved then RTO is recommended (Appendix 'E'). However, the procedure was changed in PIA where "Engine Cut" call out was to be given by FE when target N_1 could not be set. Now the decision rests with PIC, but FE's call-out for not achieving target thrust has not been incorporated in the procedures. From 80 kts to 144 kts aircraft took another 23 seconds to accelerate, yet, target N_1 could not be attained on Engine # 1 and # 2. The N_1 on Engine # 1 remained stagnant at 107.7% at the time of RTO decision. As stated by the Flight Deck crew, EGT on Engine # 4 rose to 962^{0}C instead of limit of 960^{0}C. DFDR readouts show an effort to control EGT over boost by reduction in N_1 where RPM was reduced from 114% to 111% in 12-15 second i.e. initiated at 85 kts speed. The reason for reduction in N1 from 113.5 % to 111% on Engine # 3 could not be established. The EGT over boost to 962^{0}C is no cause of alarm and flight conditions permitting it is to be brought within limits and normal operation is to continue as in Ops Manual, though, technical orders permit operations between 960-975^{0}C for a maximum of two minutes. Such normal limit excursions when

repeated 15 times, the engine goes for maintenance. It is important to note that such over boost occurrence records was not available, though; similar occurrence on the same engine had taken place previously. It may be noted that previously same PIC took off with 965°C EGT Excursion on engine # 4 and less than target N_1 on engine # 2.

52. **Crew Communication.** The crew communication ought to be standard during critical phases of flight. Take off is one such stage where at least the Flight Deck Communication amongst flight crew must be clear, precise and concise. The ops manual, check list and SOPs dictate as to what is to be said by each person on the flight deck at which stage. Adequacy of Check List steps is further strengthened by a comprehensive briefing by the Captain. The significance of briefing is paramount as all conceivable in flight eventualities, especially the multiple failures, can not be covered in procedures. The Captain on the basis of his experience and applied knowledge can fill in the gaps in procedures. Conversely, inadequate knowledge and misperceptions can complicate and aggravate an otherwise simple situation. Consistency in understanding and handling of aircraft are reflective of good training, rich experience and adequate knowledge. Furthermore, human failings are also due to inadequacies in procedures/SOPs.

53. **Adequacy of Procedures.** Following observation need attention on dictated procedures:

a. Crew Briefing as given in B-747 SOPs (May 2000) bounds PIC to be specific to Co-pilot and Flight Engineer actions up to 80 kts and V_1 to preclude any ambiguity. However, the Boeing-747 SOP (Nov, 1993) mostly quoted by the crew and a copy provided by Flight Operations, PIAC gives discretionary power to the Captain on his judgement whether to conduct the briefing or not.

b. All documents clearly give 80 kts (Appendix 'G') datum for setting power, but the SOPs Nov 1993, page 18, Para 7 ambiguously gives a remote situation where "full thrust is set at air speeds in excess of approximately 120 kts, a slight over boost will result, if computed take off power is set". Although, in this case computed power was selected before 80 kts.

c. The SOPs and Ops Manual do specify whether to RTO if target thrust N_1 is not achieved by 80 kts or up to V_1. Further more, on inquiry from Boeing, it was specified that take off power must be set by 80 kts.

d. The "Crew Briefing" in SOPs May 2000 requires FE to clearly call out the defined malfunction before 80 kts or V_1 and; in response Captain is to call stop or go. Not getting target N_1 on one or more engines is a defined malfunction.

e. Ops Manual (Appendix 'H') dictates normal operations on CF-6 Engine if EGT is 960-975 ^{0}C. It also recommends controlling EGT within limits if flight conditions permit. However, Flight Manual permits operation within 960-975 ^{0}C regimes for Normal Operations and a log of such excursions is to be maintained. In addition, (Appendix 'J') FOM dictates following.

- Minor malfunction may justify a continued take off, especially, in the marginal conditions and speed close to V_1.

- There shall be no attempt to rectify a fault during take off run.

Therefore, minor excursion of engine parameters during take off e.g. 02^{0}C higher EGT or marginally less N_1, close to V_1 should not favour an RTO decision or an attempt to bring those within limit.

f. Reject take off procedure in Ops Manual (Page04.23.05) is in following sequence for the Captain:

- Close thrust levers
- Apply Maximum wheel brakes manually
- Apply maximum allowable reverse thrust on symmetric engines
- If speed brakes did not move up automatically, speed brake lever-up.

Variation The Co-pilot is to perform or verify actions in a sequence that speed brakes operation is before Reverse thrust application. While flight engineer is also required to ensure thrust levers against stop till thrust reverse are established and then he is to check speed-brakes up.

54. As discussed earlier speed brakes' application at higher speeds is more effective as it gives 70-100% more Drag and thus 30-50% more stopping capability in conjunction with wheel brakes vis-à-vis with wheel brakes only. An RTO near V_1without speed brakes would result in a runway overshoot at 60-70 kts. On the other hand reverse thrust, though not included in FARs flight test certification, when applied promptly would give only 200-300 feet stopping distance advantage at high speed RTO. The reverse thrust application is also not immediate as it is performed in two steps and system operation time is also more. The situation is further complicated if pilot is to go on selective reverse thrust for symmetrical application. While the speed brakes have an advantage of one step action without any other limitation and these

extend immediately, the auto extension of speed brakes with reverse thrust invariably imposes unnecessary delays. The Boeing Company's recommendation on RTO emphasises on speed brakes selection after simultaneous retardation of throttles and application of maximum wheel braking.

ACCELERATION AND STOP DISTANCES

55. The assessment of take off roll distance would highlight the aircraft performance or miss-handling, if any, by the flight deck crew. Similarly, stop distance in RTO would show the aircraft stopping performance and correctness of flight deck Crew's actions.

56. **Accelerate Distance .** The DFDR does not show the aircraft speed below 50 kts, therefore, the distance for acceleration and deceleration has been calculated by basic formula. The speed for each second on DFDR has been translated into feet/second to determine exact distance travelled. The aircraft speed has been first converted into True Air Speed according to the prevailing temperature and corrected altitude at the time of the occurrence. As wind was light/variable, TAS is equivalent of Ground Speed.

Vi (Initial velocity)= 0 kts

Vf (Final Velocity)= 51.7 kts CAS, therefore,
GS/TAS= 55 kts or 92.95'/sec at 2000' AMSL, 29^{0}C and; Wind Light/variable

t (Acceleration time)= 18 seconds

S_1= Acceleration Distance

a (acceleration)= ?

$$\mathbf{Vf = vi + at}$$

$$\textbf{or} \quad \mathbf{a = \frac{Vf - Vi}{t}}$$

$$a = \frac{92.95 - 0}{} = 5.164'/sec^2$$

18

Further more,

$$\mathbf{2aS_1 = Vf^2 + Vi^2 \quad or \quad S_1 = \frac{Vf^2 + Vi^2}{2a}}$$

$$S_1 = \frac{(92.95)^2 + (0)^2}{2x\ 5.164} = 836'$$

Stop Distance

Vi = 50 kts = 53 kts TAS/GS = 89.57/sec

Vf = 0

t = 17 sec

a = ?

S_2 (Stop Distance) = ?

$$\mathbf{Vf = Vi + at \quad or \quad a = \frac{Vf - Vi}{t}}$$

$$a = \frac{0 - 89.57}{17} = -5.269'/sec^2$$

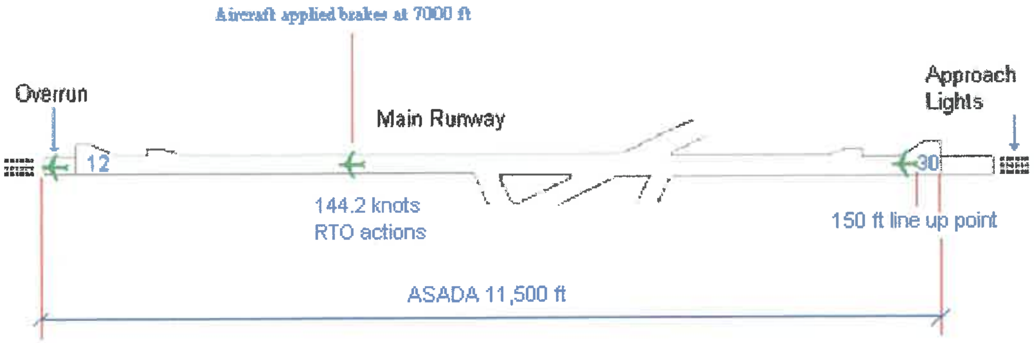
$$S_2 = \frac{Vf^2 + Vi^2}{2a} = \frac{0 + (89.57)^2}{2x\ 6.5}$$

S_2 = 761'

Calib Air Spd	TAS/GS	Distance/Sec	Total Dist
51.7	54.802	92.61538	
56.3	59.678	100.85582	
51.7	54.802	92.61538	
56.3	59.678	100.85582	
59.9	63.494	107.30486	
62.6	66.356	112.14164	
64.7	68.582	115.90358	
67.7	71.762	121.27778	
73.5	77.91	131.6679	
76.3	80.878	136.68382	
79.5	84.27	142.4163	
81.5	86.39	145.9991	
84.5	89.57	151.3733	
88	93.28	157.6432	
90.4	95.824	161.94256	
94.7	100.382	169.64558	
94.3	99.958	168.92902	

100	106	179.14	
101.9	108.014	182.54366	
104.2	110.452	186.66388	
107.7	114.162	192.93378	
112.3	119.038	201.17422	
114.3	121.158	204.75702	
117.1	124.126	209.77294	
119.2	126.352	213.53488	
122.4	129.744	219.26736	
126.3	133.878	226.25382	
128.7	136.422	230.55318	
132	139.92	236.4648	
132.9	140.874	238.07706	
136.1	144.266	243.80954	
139.5	147.87	249.9003	
142.4	150.944	255.09536	
144.2	152.852	258.31988	5744.66 ft+836=6580 ft
141	149.46	252.5874	
136.4	144.584	244.34696	
131.2	139.072	235.03168	
126.8	134.408	227.14952	
118.3	125.398	211.92262	
112	118.72	200.6368	
105.9	112.254	189.70926	
101.1	107.166	181.11054	
100.9	106.954	180.75226	
93.3	98.898	167.13762	
88.9	94.234	159.25546	
84.8	89.888	151.91072	
80.4	85.224	144.02856	
75.5	80.03	135.2507	
72.5	76.85	129.8765	
67.7	71.762	121.27778	
63.9	67.734	114.47046	
59.8	63.388	107.12572	
59	62.54	105.6926	
55.2	58.512	98.88528	
53.9	57.134	96.55646	
50	53	89.57	3544.284 ft +761=4306 ft

Total R/W consumed=4306+6580=10886 feet



57. If one aircraft length is subtracted from ASDA due to back track and line up on Islamabad runway 30 and one aircraft length for line-up/ at stop; then accelerate and stop distances in this incident equals to accelerate and stop distance available when abort was initiated at 144 kts CAS. At airfield limit weight for runway 30 Islamabad, as this flight was, acceleration distance to V_1 is 6900 feet (60% of runway length) and remaining 4600 feet (40 % of runway length) is stopping distance. Further more, as aircraft was 3 second short of V1, therefore, there was an additional margin of 750 feet in stop distance. Similarly, then another 600 feet were available as abort was initiated 10 kts less than V_1. It may be noted that use of reverse thrusts give 200-300' stopping distance advantage and accomplishment of abort actions in one second give 600-700 feet stopping distance advantage if RTO is initiated at V1. In nut-shell, abort at 144kts should have been accomplished with an advantage of 1500 feet with use of Reverse Thrusts, giving the pilot 03 seconds to complete abort actions.

58. **Acceleration/ RTO at V1.** If the take off was aborted at V1 i.e. 3 seconds later as acceleration was @ 3 kts/sec, then accelerate distance is calculated about 7300'. It shows that aircraft acceleration was almost 400' slower over a distance of 6900'. Similarly, if braking energy is kept linear and constant for abort at V_1 as in this particular case with same sequence of abort action, then stop distance available would have reduced by 400 feet. In

actual overshoot would have been much higher due to 250 feet line up margin and braking energy rise not being linear with increase in speed. These calculations also reflect that in this incident aircraft would have stopped 1500 feet before end of runway if actions of abort were completed in three seconds as recommended by Boeing Company.

59. From these inputs following questions arise:

a. Was the aircraft acceleration satisfactory?
b. What was the cause of slow deceleration?
c. Was the decision of Abort correct and timely?

60. **Aircraft Acceleration.** It is evident from mathematical calculations that aircraft acceleration distance in terms of distance was 300 feet more over 6900' till reaching V_1 or acceleration distance at the time of abort was 260 feet more. Poor acceleration may be due to following:

a. More than given TOGW
b. Less Engine Thrust
c. Catchy brakes
d. Weather parameters inaccurate

a. **More than given Take off weight.** The weight and balance Para highlights the weaknesses in the entry of fuel and passenger baggage in the load sheet. It is established that fuel entry was 1.5 tonnes less and cargo load was 600 Kg less. But passenger baggage entry was 2.2 tonnes more than the re-weighed baggage after the incident. Therefore, actually aircraft was marginally less than the MTOGW, if weighing of baggage by Islamabad PIA traffic staff was correct and if it is assumed that personal baggage in the cabin was within stipulated limits. Hence, poor acceleration may not be due to more than given MTOGW.

b. **Less Engine Thrust** The engine performance was clearly less than the target requirement right from brake release to initiation of abort. The aircraft take off performance is calculated on the basis of requisite take off thrust availability by 80 kts. It is evident from DFDR readouts that thrust on Engine # 1 and # 2 was less by about 6% and 5% N_1 value. Though, the disparity of N_1 on Engine # 1 remained till abort decisions speed but Engine # 2 disparity reduced to 1.5 % N_1. However, Engine # 3 & # 4 target N_1 were reduced to control EGT over boost of 962^{0}C (02C^O more) by 3% average N_1 RPM. It is important to note that CF-6 engines produce 95% take off thrust at 97% N_1, which was available at the time of brake release. Besides, increase in thrust with increase in N_1 to maximum thrust is not linear, however, for ease of understanding it may be considered linear from 97% to 113.8% N_1 over the range of 5 % remaining take off thrust. That means 5-6% less N_1 on each engine would constitute about 1.5% less thrust on each engine. As the N_1 values on other two engines were also reduced by about 3%, therefore, thrust reduction on Engine # 3 and # 4 would have also reduced by about 0.75% approximately. On the basis of these thrust values the overall thrust reduction on the aircraft would have been about 1 to 1.5% less than required targeted thrust. This shortfall in the thrust available may have manifested in 260' more take off run up to 144 kts.

c. **Catchy Brakes:** The aircraft take off acceleration is adversely affected if one or more brakes are catching. Similarly, if anti skid system performance is not optimum/even on all brake assemblies then stopping distance would be more. Both the factors individually and in unison would be manifested in Accelerate and Stop Distance. However, in less than optimum performance of brakes / anti-skid systems, many tell-tail evidences would be available, which are as follows:

i. Due to catchy brake associated tyre would leave skid tyre marks on the taxi way/ R/W.

II. Due to catchy brake over heat warning would come on during taxi/take off roll.

III. Aircraft directional Control would be abnormal during taxi, take off and abort with unsymmetrical brakes.

IV. Anti-Skid malfunction during abort roll would be visible in quick over heating of brakes or uneven temperature rise on brake indications.

V. Skidding marks on tyres

VI. Due to uneven braking, disparity in rise of temperature beyond tyre fuse plugs blowing would cause tyres' deflation at different stages of abort.

61. In this incident the aircraft was at MTOGW and all braking devices were not used simultaneously up to 101 Kts, yet, the brakes and anti-skid systems performance was optimum, as none of the above evidence was found on the aircraft or RW after the incident. If abort actions were taken promptly even at 115 Kts or so with maximum wheel braking, the tyres fuse plugs would have caused deflation. However, with the use of reverse thrust and more stop distance available the maximum wheel braking with speed brakes is not required; therefore, tyre fuse plug blowing speed would increase with same weight. If abort was initiated around 120 Kts then stop Distance Available would have been 7500' as against 4600' at 144 Kts and resulted in a non-event. In this particular case none of the tyres skidded, busted or deflated during abort roll and

all tyres fuse plugs blew away only after the aircraft had come to a complete stop.

62. **Weather Parameters:** The Flight Deck crew calculated the take off performance correctly according to the meteorological briefing. The same parameters were used by other aircraft just before this incident and no complaint was received on the inaccuracy of meteorological inputs. Additionally, the weather parameters of few days before and after the incident and those generally prevalent during the period of cycle of the year conform to the prevailing weather parameters of the time of the incident.

63. **The Incident.** On AP-BAK PK-717 at Islamabad on 20 July 2003, following procedures were straddled vis-à-vis SOPs and FCOM:

a. Reject Take off Crew briefing was not performed. The opinion of the Captain "Standard Briefing" comment was insufficient in line with SOPs (2000 Edition). Although he was aware of the extra ordinary technical history of the aircraft and MTOGW. On the subject of Crew Briefing the Captain gave conflicting statement initially but later stuck to the version, as stated above, which is in conformity with the statements of other crew.

b. Due to MTOGW Captain opted for static take off at 97-98% N_1 instead of 70% N_1. Such a high RPM at brake release rules out the possibility of poor engine spool up time or split in engines acceleration. None of the flight crew was aware of reasons for restriction of maximum 70% N_1 on static take off.

c. In the absence of a specific call-out for power availability at 80 kts, the Flight Engineer called Engine # 1 performance in a long narration for Captains knowledge. At this stage Captain was to observe and take a decision of Go/No Go. The Captain decided to go after observing engine instruments in spite of not achieving target N_1 on Engine # 1 and # 2. His decision of "Go" was manifested in his announcement that "With Ram air N_1 will Increase". A rapid thrust lever advance above 120 kts may result in engine parameter over boost but at fixed thrust lever setting ram-air pressure does not increase the engine RPM. The Go decision was also influenced by a previous snag of similar nature on Engine # 2 where Captain continued take off and completed the sector successfully.

d. The Flight Engineer then announced problem with Engine # 2 and also announced EGT over boost to 962^{0}C (normal 960^{0}C). The Captain again observed the Engine's parameters and decided to abort at 144 kts without announcing his decision. Although, Engine # 2 N_1 had increased, at the time of abort, from 108% to 112%. At the same time EGT over boost by only 02^{0}C at critical stage of flight did not call for a reject take off. The FOM and technical orders consider this within limit if excursion is less than 975C^O, especially when Captain had taken off normal with higher EGT excursion on 27 June, 2003. The decision of not aborting right after call-out of 80 kts on a discrepancy for which "No Go" is recommended and, aborting close to V_1 when one of the Engine performance had improved reflects state of confusion and indecision on part of the Captain. At the same time power on Engine # 3 and # 4 was reduced. The indecision / confused state might have been caused by long call-out by the Flight Engineer in the absence of clear-cut procedures. The RTO decision came at a time when aircraft acceleration was normal i.e. 3-6 kts/sec and there was no indication about aircraft not getting airborne safely. The continuation of take off after an engine flame out one second before V1 ensures 35' at the end of ASDA as against 150 feet with all four engines operating. A Go decision 2 seconds before V1 engine flame out would also give 30 feet at the end of runway. Therefore, continuation of take off at 144 kts after ignoring non-availability of thrust at 80 kts would have been a non-event as in case of 27 June, 2003 case with the same PIC. In the light of foregoing following is summarized on the decision making:

i. Non application of experience and airmanship.

ii. Inadequate knowledge of aircraft performance and procedures.

iii. Absence of clear call-outs for Flight Engineer on power availability in the procedures.

iv. Inconsistent decision/actions for similar malfunctions on different occasions.

64. <u>Abort Actions</u>. The RTO was not announced by the Captain. His action of thrust lever retardation to mechanical stop and application of wheel brakes was simultaneous. The RTO actions in FCOM and SOPs give reverse thrust application resulting in auto speed brakes deployment. While Boeing's presentation on RTO emphasizes on raising of speed brakes within 3 seconds of thrust lever and wheel brakes application. The reverse thrust was deployed without increase in N_1 after 08 seconds which resulted in speed brakes deployment delay by 09 seconds at about 100 kts. The high speed decelerations took place by wheel brakes only and resulted in quick rise of brake temperature. Interestingly, Co-pilots actions in Ops-Manual give precedence to speed brake deployment over reverse thrust. During the interview PIC highlighted the problem with # 2 and # 3 engines' reverse thrust engagement, though, cockpit crew did not record a reverse thrust snag in Tech Log. It may be noted that snag entries on the Tech Log were made after detailed discussion/consultations in the cockpit after the incident, as evident from CVR extracts. Furthermore, there has been no snag on reverse thrust many sorties before or after the incident.

65. **Weight and Balance.** The subject has been discussed at length in above paragraphs. In this part operational matters have been discussed. The engineering serviced the requisite fuel, yet, PIC requested for four tonnes more for no apparent reason and it was not recorded in Flight Plan. PIC's logic is based on the ATC climb out en-route Sanam, where with MTOGW it is not possible to reach required altitude; therefore, climb is achieved overhead before proceeding out bound. However, Flight Engineer attributed change of diversion from Birmingham to London Heathrow as desired by the Captain in PIA operations and for longer holding. Effort was not made to resolve the conflicting statements to avoid friction amongst flight crew. Informally, all flight crew showed their reservations on cargo/baggage load accuracy on load sheet, which was substantiated by their experience of fuel consumption vis-à-vis calculated fuel. In this particular incident the inaccuracy in passenger baggage weight is established. Incorrect calculation of serviced fuel and its entry in load sheet by 1.5 tonnes less is yet another factor that makes the given aircraft take off weight a suspect. Though, in the end, reason may be voiced that less than entered baggage load catered for more fuel in the aircraft. It may also be noted that after the incident the cargo/passenger's baggage was not weighed by an independent team. In addition, it is a known fact that hand carried baggage by passengers is always more than the prescribed limit. This picture leaves ambiguity about the

MTOGW of the aircraft at that time, resulting in obvious effect on aircraft take off and RTO performances.

CF6 Power plant

66. As per engine manufacturer, the static thrust at sea level with a rate of temperature of ISA plus 15 is 51,800. Whereas there is no lower tolerance of N1 and at full take-off power the engine has to achieve the target N1. As per the aircraft manufacturer there are no provisions in the regulation which may allow the pilots to take-off when achieved power is less then set for take-off. The aircraft performance is based on having the required N1 at 80 knots. In this particular case, the pilot did not achieve the required N1 on # 1 and # 2 engines at 80 knots and continued up to 144 knots when the deceleration started. As per pilot statement, the Captain continued as the RPM would have increased by the Ram Air.

67. At take-off the EGT should not exceed 960 ^{O}C for more than 02 minutes. These excursions are to be noted and entered in the technical log. The EGT may exceed for any period provided it is noted by the crew since inspections are required to be carried out (Refer AMM 72-00-00 page 680F. For this particular engine only 15 excursions are allowed. The manufacturer further states that there is no limit for spool up time from ground idle to take-off thrust. The only measurement the engine must satisfy is acceleration from flight idle. The spool up time from flight idle to 95% of take-off thrust, which is 97% of take-off N1 and is achieved in 8 seconds or less (Appendix 'K') and at 113% of take-off N1 the engine should achieve 100% of take-off thrust. Hence the difference from 95% to 100% is 5% and the difference between 97% N1 and 113% N1 is 16%, which means that 1% of take-off thrust equals 3% N1. Hence engine No. 1, which had achieved 107% N1, had 98% take-off thrust. Similarly, engine No. 2 had achieved 110% N1 and had 99% take-off thrust. It may be noted that the spool up time up to 70% is

slower after which it gains momentum. Hence due to engine spool up at a higher RPM the N1 split between the engines is less.

68. The CF-6 engine used on B-747 is also installed on Airbus-300. A new engine completes it life cycle on A-300 B-4 and then after overhaul and some modifications it is installed on B-747. The engine overhaul requires complete replacement of vital components like compressor / fan / turbine blades etc. However, PIAC engineering replaces these parts on condition for engines' of B-747. These measures have been instituted to reduce the overhaul costs. The engines overhauled on these lines are restricted on full power take off and on maximum permissible EGT. However, due to the nature of B-747 operations pilots are constrained to use maximum take off power due to limit take off loads and available runway length. More than recommended operating limits on the B-747 engines, therefore, result in frequent short falls in engine performance at max power.

69. **Ram Air Effect During Take-Off Run**. The N1 compressor has two functions. The first is to accelerate secondary airflow into the fan duct and the second is to provide the N2 compressor with super-charged compressor air. The N1 compressor is mechanically coupled with the N1 turbine, and the N2 compressor is mechanically coupled with the N2 turbine. The CF6 engine is N2 governed engine (controlled by the N2 compressor). During start up the N2 is rotated first, which moves the N2 turbine and then the N1 turbine. Since the N1 turbine is mechanically coupled with the N1 compressor, therefore the N1 compressor starts moving. Both N1 and N2 compressors are aerodynamically coupled with one another, therefore when N2 is increased N1 will increase accordingly and vice versa. The Main Engine Control (MEC) unit, which controls the Variable Stator Vanes and fuel based on the input it receives from the N2. Once

the throttle is opened to full and the N2 reaches to it max, the MEC will supply a controlled amount of fuel with a fixed position of the VSV which will keep the N2 at its required speed. As the throttles are moved to maximum position, N2 will reach its max speed, hence air will be drawn accordingly. Increasing the aircraft speed will not increase the incoming air since the MEC controls the incoming air mass as explained above. Therefore, the ram air will have no visible effect on N1.

70. **Maintenance** – Seeing the pattern of defect rectification, it is observed that the defects are not analyzed by the AME before carrying out the rectification. Mostly a tendency of preventative maintenance has developed in the engineering department. The concept of hit and trial is also being used instead of troubleshooting. The engine is delivering normal power after changing the Variable feed back cable and Variable actuator which could not be detected after two previous aborts.

71. **Organization policies** – A number of overwriting were noted in the flight plan. The excess of fuel, baggage and cargo on board the aircraft show poor communication, lack of coordination amongst the different departments.

FINDINGS

72. The Findings of this investigation have been categorized as Latent Failures and Active Failures, which resulted in the RTO at high speed. The Latent Failures are those failures, which are of recurrent nature and those are not the cause of occurrence directly. Though, higher frequency of recurrence would finally result in accidents/incidents. The Active Failures are those failures, which always result in an accident/incident directly. For example, an engineering maintenance failure resulting in engine fire or incorrect pilot actions are

categorized as Active Failure, while low engine performance and inadequate procedures are examples of Latent Failures.

73. **Latent Failures**

a. The aircraft had a history of less than target take off thrust on Engine # 1 and # 2.

b. Aircraft had EGT Excursion history on Engine # 4.

c. PIC of the incident had taken off with less than target take off thrust on Engine # 2 and EGT excursion on Engine # 4 on the same aircraft about 23 days before this incident.

d. In the last 15 days, take offs were rejected twice around 100 Kts by two other Captains due to same reasons.

e. The aircraft was at its maximum gross take off weight, however, load sheet showed many inaccuracies in Fuel Weight and passenger baggage weight.

f. The fuel entry on load sheet was 1.5 tonnes less than actual and passenger baggage entry was estimation. The baggage weight on the check-in counter was almost two tonnes less when weighed by PIA Traffic Staff after the incident. Similarly, actual Cargo Weighed 0.5 tonnes more than the load sheet entry.

g. Cockpit Crew was aware of the reasons which resulted in RTOs on previous occasions.

h. PIC did not cover the Crew Briefing with cockpit crew contrary to SOPs (May 2000) and used his discretion as empowered in cancelled SOPs (Nov 1993).

i. SOPs/FCOM/ Boeing Company recommend RTO if take off target N_1 is not achieved by 80 Kts. Though, such Call-out by FE is not given in procedures.

j. RTO sequence in Ops Manual is not in conformity with Boeing's recommendation on use of Speed Brakes, although, CO-Pilot's sequence of actions is in conformity with Boeing. The check list steps for PIC on RTO would always result in an over shoot at high speeds.

k. Call-outs by Flight Engineer on engines' performance during take off roll were ambiguous and long.

l. Captain and Co-Pilot's knowledge on engine performance was inadequate, which is the cause of handling similar failure differently on other occasions.

m. In spite of lower than target take off N_1, (about 1% to 1.5% less than required thrust), the take off roll distance at time of abort i.e. 144 Kts, was about 300 feet more than normal take off roll with full thrust.

74. **Active Failures**

a. On Flight Engineer's Call observing less than target N_1 on Engine # 1 after 80 Kts Captain continued take off after announcing that with ram air the RPM would increase, a wrong assumption.

b. Flight Engineer called out that N_1 on Engine # 2 was less and EGT excursion on Engine # 4 in an unusually long sentence in vernacular. It was due to the absence of unambiguous call-out in the SOPs/Check List for Flight Engineer.

c. The abort decision was taken late for less take off thrust, though, same engines' performances were indicated at 80 kts.

d. Abort actions on selection of reverse thrust and speed brakes were completed in 08 second at 101 Kts while line pilots are expected to complete RTO actions in maximum 03 seconds. Accomplishment of the same in one second gives an advantage of 600-700 feet stopping distance close to V1

e. Thrust Reversers remained in interlock position till aircraft came to a halt i.e. remained ineffective as N_1 on all engines was not increased. ?

f. Flight Engineer and Co-Pilot did not ensure completion of RTO action in line with Ops Manual/ Check list, though; PIC also did not announce his decision of abort.

75. **Additional Information**

a. There was no additional indication in the cockpit at the time of abort decision, which was not present at 80 kts that raised doubts about aircraft not getting airborne safely after 3-4 seconds.

b. On abort the aircraft brakes / anti-skid systems functions were optimum.

c. CVR circuit breaker was not pulled out by cockpit crew, which did not preserve the cockpit communication during entire incident and this action has not been included in procedures.

d. In previous two RTOs the decision/correct actions were taken at about 100 Kts for similar malfunctions and those were non-events.

e. The use of water to cool the red-hot brake assemblies caused quenching of metal and jamming of brakes, which resulted in prolonged non-availability of the runway for operations at Islamabad Airport.

Primary Cause of Incident

76. Primary cause of incident is Human Factor resulting due to omission of Crew Briefing, late RTO decision and incorrect RTO actions.

Contributory Causes of Incident

77. a. Insufficient Take off Call-Out Procedures.

b. Inadequate RTO Procedures

c. High Frequency of Engine malfunctions and inadequate maintenance work.

Recommendation

78. Following is recommended:

a. The Cockpit Crew is recommended for CRM refresher and supervised training sessions. (Implemented on the findings of Interim Report).

b. Speed Brakes manual raising to be included in RTO sequence after Thrust Lever retardation and maximum braking, and then, followed by symmetrical use of reverse thrust.

c. Old SOPs (issue 1993) to be cancelled.

d. The load sheet preparation be factual and made on scientific procedures.

e. All stations should have computerized Weighing Bridge to weigh all the pallets/ trolleys and the actual weights be automatically transferred on trim sheet.

f. Snags on engine take off power be cleared by Senior Engineers from Quality System.

g. DFDR, PMR and CVR equipment to be periodically checked for serviceability and included in C of A.

h. The step for CVR preservation of occurrence duration to be made part of FCOM instead of OETB.