BAe 146, EI-CMY, 25 June 1997

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Aircraft Type and Registration:	BAe 146, EI-CMY
No & Type of Engines:	4 ALF502 turbofan engines
Year of Manufacture:	1985
Date & Time (UTC):	25 June 1997 at 0843 hrs
Location:	London City Airport
Type of Flight:	Public Transport
Persons on Board:	Crew - 5 - Passengers - 49
Injuries:	Crew - Nil - Passengers - Nil
Nature of Damage:	Nil
Commander's Licence:	Airline Transport Pilot's Licence
Commander's Age:	30 years
Commander's Flying Experience:	3,277 hours (of which 835 hours were on type)
	Last 90 days - 182 hours
	Last 28 days - 73 hours
Information Source:	AAIB Field Investigation

History of flight

The aircraft was on a scheduled flight from Dublin to London Cityand was making an approach to Runway 28. The airport had beenusing Runway 10 and this was the first approach to the westerlyrunway that morning. At 0820 hrs, the airport 'Automatic TerminalInformation Service' had transmitted information 'Hotel'; thishad been received by the crew and it included the following weatherinformation: Surface wind 180°/07 kt, varying between 110°and 300°; visibility greater than 10 km; light rain; cloudfew at 1,800 feet and broken at 4,800 feet; QNH 1004 mb. Withthis weather information, the crew had requested, through ThamesRadar, if they could use Runway 28 for landing; this was agreedby London City ATC and the crew were informed.

The commander was the handling pilot for the approach and carriedout a normal 5.5° glide slope ILS approach to the runway. As part of the approach checks the wheel brake hydraulic systemwas

changed to 'green' and the brake pressure checked at whichtime it was confirmed that 3,000 psi each side was registeredon the gauge. With Flap 33° selected, the aircraft was stabilisedat an approach speed of Vref plus 5 kt; this was an indicatedairspeed of 115 kt. EI-CMY was cleared to land at approximately7 miles range and the crew were also advised that the runway wasdamp and that the surface wind was 170°/09 kt; this equatesto a tailwind of 3 kt. At 2 miles, the crew called for a windcheck and ATC transmitted that the wind was 160°/08 kt; thisequates to a tailwind of 4 kt. The crew considered that touchdownwas at the end of the touchdown zone, close to the 'end of zonelights'. Then, once the nosewheel was on the ground, the commanderactivated the spoilers and the first officer confirmed their deployment. However, when the commander commenced wheel braking, she consideredthat the brakes were 'snatching' and that the retardation wasless than normal. She continued to apply foot pressure to thewheel brakes and both crew members confirmed that the brake pressuregauges were indicating normal values. As the aircraft approachedthe end of the declared runway, the commander changed the operatingwheel brake hydraulic system from 'green' to 'yellow' and askedthe first officer if he was on the brakes. The commander hadalso maintained pressure on her brake pedals and the crew thenfelt an immediate improvement in the braking performance of EICMY. The commander was now confident that the aircraft would stopwithin the hard standing and, in consideration of passenger comfort,reduced the brake pressure slightly; the aircraft stopped justshort of the grass. EI-CMY travelled beyond the end of the declaredrunway, past the 75 metres 'Runway Starter Extension' and intothe final 24 metres hard standing surface.

The ATC controller had watched the aircraft land towards the endof the touchdown zone and thought that it appeared faster thannormal as it progressed along the runway. As EI-CMY passed thecontrol tower, the controller considered that it could overrunthe runway and pressed the crash alarm; thereafter, she monitoredthe aircraft and noted that it seemed to 'snake' as it passedinto the 'Starter Extension' and then saw it come to rest shortof the grass; as it stopped, the controller noticed a short 'puff'of smoke from the area of the right gear and asked the crew ifthey required any assistance. When the crew of EI-CMY transmittedthat they were serviceable, the controller gave them permissionto taxy to the parking area. Shortly afterwards, when the AirfieldFire Service (AFS) checked in on the radio, the controller advisedthem of the situation, stood them down from the 'alert' but askedthem to attend the aircraft on the stand. The AFS checked theaircraft on stand and then, after confirming that there was noevidence of excessive heat in the area of the brakes and wheelsof EI-CMY, were stood down.

Engineering investigation

Witness markings on the runway which appeared to be caused bythe incident aircraft were found on the starter extension at thefar end of the landing runway. A very limited amount of rubberhad been laid down and there was also some scalding of the whitepainted markings where the tyres had crossed them. The markshad been made by main wheel tyres, and showed that the aircrafthad swung to the left at the end of its landing roll. A numberof other marks existed which were associated with the subsequentturn, and there were also some marks which were clearly not associatedwith this aircraft. In all, the relevant marks were consistentwith braking following the drop-out of the anti-skid system whichnormally occurs at low speed. No evidence of anti-skid malfunctionwas observed from the ground marks. Smoke or steam had been reportedcoming from the area of the landing gear at the end of the landingrun; in the opinion of the engineer who examined the aircraftat the time, this could have been due to the dampconditions and the heat generated by the braking action,as there was no evidence of gross overheating.

Immediately after the incident, the green and yellow brake systemswere bled in accordance with Chapter 32-40-00 of the MaintenanceManual. Air was found in the port outer and starboard inner brakeunits. The amount was small and it was considered that it wouldnot have reduced the braking effort. Following this, theanti-skid system was tested in accordance with the MaintenanceManual and was found to be serviceable. Additionally, two taxiruns and brake tests were conducted, testing the brakes and spoilerson both green and yellow systems. The only defect found was onthe green brake system pressure gauge which had a spurious indication. As permitted by the MEL, the aircraft was despatched to Dublinwhere the defect was cleared by replacing a brake pressure transmitter.

At Dublin, the aircraft was extensively re-checked and severaltaxi and brake test runs carried out. No further air was found,and the green and yellow system checked out normally. Althoughno faults were found, the anti-skid control unit was changed asa precaution. Following this, further taxi tests were carriedout; the flight crew who carried out the taxi and brake testsexpressed a subjective view that the braking was more effectivewith the new unit fitted.

On 20 June 1997, five days before the incident, another Captainmade the following entry to the Technical Log: *"Checkanti-skid Green control valve anti-skid not working properly skippinghad to select yellow two landings in a row"* . Maintenanceaction was a check of the anti-skid system in accordance withthe Maintenance Manual. No fault was found, the rectificationbox includes the comment *"please report further"*.

The anti skid control unit, part numberA20556, serial GX212, which had been removed at Dublin, was sentto the manufacturer for testing with the AAIB in attendance. It had first been supplied in June 1995 and this was its firstreturn to the manufacturer. The unit consists of five circuitcards; a power card which is common and four wheel cards. Each wheel card has wheelspeed processing circuitry plus greenand yellow output modules. Thus, multiple card failures wouldbe required to cause the loss of braking on more than one wheel. Power card failure would not inhibit braking but would mean thatanti-skid protection would not be available.

The anti-skid control unit was giventhe normal acceptance test using Automated Test Equipment (ATE)and passed as serviceable. After this, it was subjected to 9hours of vibration testing with temperature cycling. During thistime, the No. 3 card exhibited a hard fault which would have preventedit from sensing a wheel speed transducer failure, and was alsofound to be slightly outside calibration limits. However, neitherof these defects would have had any effect on the unit's operationin the aircraft.

Between the removal of the anti-skid control unit and the testwork, the aircraft flew a further 100+ sectors without recurrence,and no further anomalies have since arisen. It has not thereforebeen possible to positively identify a fault with the aircraft.

Optional modification HCM01040A, which has been fitted as standardto all aircraft manufactured since December 1989, introduced anincreased angle to the toe brake pedals. The relevant ServiceBulletin stated: "The existing toe brake pedal angle hasbeen criticised by some pilots who have found it awkward to applyfull brake pressure." This optional modification was notembodied on any of the operator's aircraft.

Flight recorder information

The Flight Data Recorder, a PV1584, was removed and replayed atthe AAIB. Figure 1 shows selected parameters from the approachand landing at London City. The aircraft passed the a heightof 35 feet at 120 kt IAS and at touchdown, which was identifiedfrom the normal acceleration of 1.45g, the airspeed was 106 kt. The spoilers were deployed between two and four seconds later;it is not possible to be more precise since this discrete parameteris only sampled every two seconds. Once the spoilers weredeployed, from an airspeed of 98 kt the aircraft began to deceleterateinitially at a level of 0.25 to 0.3g; the total time from deploymentof the lift spoilers until the aircraft stopped was 24 seconds. After around 13 seconds, with the aircraft at an airspeedof approximately 65 kt, the decelerationdecreased to a level of 0.1g for roughly three seconds. The decelerationthen increased to a level of between 0.3 and 0.4g for around 7seconds before the aircraft came to a stop; the airspeed doesnot indicate below 50 kt. During this final deceleration phasethere was a turn to the left of roughly 10° onto a headingof 270°. Braking parameters are not recorded by the FDRso it was not possible to determine the level of braking applied.

A double integration was performed from the recording of longitudinalacceleration in order to calculate the stopping distance, andtherefore the touchdown point. The total ground run was calculatedas 900 metres from touchdown to the aircraft coming to acomplete stop. The touchdown point was calculated and, withinthe accuracy of the method used, was therefore consistent withthe witness reports.

The manufacturer used their performance data to calculate an unfactoredstopping distance in the conditions pertaining, ie the distancethat the aircraft would use to stop, from a speed of 98 kt, usingwheel brakes and lift spoilers. The time to stop is given inparentheses, for each case. The results are detailed below:

Maximum application of wheel brakes and lift spoilers deployed:

	Dry	Wet
Zero wind	399 metres (14.0 seconds)	568 metres (21.5 seconds)
5 kt tailwind	430 metres (14.5 seconds)	621 metres (22.7 seconds)
7 kt tailwind	443 metres (14.8 seconds)	643 metres (23.1 seconds)

Half maximum application of wheel brakes and lift spoilers deployed:

	Dry	Wet
Zero wind	587 metres (23.0 seconds)	791 metres (33.1 seconds)
5 kt tailwind	639 metres (24.1 seconds)	869 metres (34.9 seconds)
7 kt tailwind	661 metres (24.6 seconds)	901 metres (35.6 seconds)

A simulation performed by the manufacturer reproduced the decelerationprofile and ground roll distance using the following assumptions:

a) 7 kt tailwind,

b) medium braking action on first brake application (green) anda braking action between maximum wet and maximum dry braking onthe second brake application (yellow),

c) 0.5 second delay switching from green to yellow brakes,

d) 90% effectiveness of lift spoilers due to application of forwardstick after touchdown.

Airfield information

London City Airport is situated in the dockland area of the city;it has a single runway which is designated 10/28. Informationcontained within the UK Aeronautical Information Publication (UKAIP)includes the fact that the Landing Distance Available (LDA) ineither direction is 1,199 metres; there is also a footnotestating that these distances include a 75 metre starter extensionfor Runway 10 and a 186 metre starter extension for Runway 28. These footnotes are confusing as the starter extension distancesare not included in the LDA. Additionally, there is an extra24 metres of hard standing at each end of the starter extensions;this information is not included in the UKAIP. Following thisincident, the airport authorities submitted an amendment to theUKAIP to clarify the information relating to London City Airport.

There are standard threshold markings and lights for each runwayand the end of each touchdown zone is marked by white lights insetin the runway 336 metres from the threshold. The approach andrunway lighting and PAPIs are set for a 5.5° approach. Forsteep approaches, the screen height has been reduced from thenormal 50 feet to 35 feet.

After the incident, a runway braking inspection was carried out;this was done some 2 hours and 20 minutes afterwards andrain had continued during the intervening period. The runwaywas then assessed as wet and the inspection included both directionsand on both sides of the runway. The lowest Mu-meter readingwas .45; braking action is good when the Mu-meter reading is .40and above.

The UKAIP details the procedures which ATC will use for reportingthe presence of water on the runway. On this occasion, the runwaywas reported as 'Damp' indicating that the surface was showinga change of colour due to moisture. The next level would be 'Wet'when the surface is soaked but no significant patches of standingwater are visible. The UKAIP also includes the information thatpilots may assume that an acceptable level of runway braking frictionis available with conditions of 'Damp' or 'Wet', unless the runwayhas been notified as "liable to be slippery when wet". This notification is required when the friction characteristicsof a runway or a significant portion thereof deteriorate to aMu-meter calibration value of 0.39 or less; this was not applicablein the case of the runway at London City Airport.

During the investigation to a similar incident to another BAe146 at London City Airport on 18 November 1996, reportedin AAIB Bulletin No 8/97, the airport authority stated that theywere considering some form of ground arrester system at both endsof the runway. This installation was completed on 18 August 1997.

Operating information

The commander was well experienced in operating into London CityAirport and had completed 64 previous landings there; ofthese, approximately 30 had been in wet/damp conditions. Thefirst officer was also experienced with 2,100 hours total flyingand 1,600 hours on type.

At touchdown, the aircraft weight was calculated as 31,952 kg;from the company manuals, the required Vref for this landing weightat 33° flap is 110 kt.

The factored landing distances, calculated by the manufacturer,at 32,000 kg, +11°C and sea level were as follows:

	Dry	Wet
Zero wind	928 metres	1066 metres
5 kt tailwind	1030 metres	1184 metres

The landing distances are measured, assuming Vref at a screenheight of 35 feet, and with maximum braking on the runway. Themeasurements are then factored by 1.67 for a dry runway and 1.92for a wet runway to allow for operational contingencies.

Company procedures and manuals

The company procedures for take off and landing at London Cityare similar to other companies operating the same type. The handlingpilot will always be the commander unless the first officer hasat least 1,000 hours on type; additionally, the handling pilotmust have completed specific London City simulator training anda line check. Wind limitations include a crosswind limit of 20kt, including any gusts and a tailwind limit of 5 kt.

Approach procedures require the aircraft to be configured withgear down and full flap (33°) and to be stabilised at Vref+5 kt before glideslope intercept; as the glideslope is intercepted,the airbrakes are selected out. This configuration is maintainedwith a target speed over the threshold of Vref. At the threshold,the throttles are retarded to flight idle as the flare is commenced. After touchdown, the throttles are reduced to ground idle and,with the nose wheel on the ground, the commander deploys the liftspoilers. The non-handling pilot confirms that the spoilers havedeployed and checks the brake pressure. If it appears that theaircraft will touchdown beyond the touchdown zone, a go-aroundmust be initiated before aircraft touchdown.

Company performance manuals include a sheet for landing limitations;this details the performance limited weight for wet or dry runwaysfor various tail and head winds. The limit for a Flap 33°landing with zero wind is 35,389 kg; for a 5 kt tail wind component,the limit is 31,078 kg; there are no limits displayed for tailwind components between zero and 5 kt.

Summary

The landing weight was below that required for the runway andthe prevailing conditions. However, this incident highlightedthe large difference in weight limitations, between zero and 5kt tail wind components, contained in the company manuals. Although,there are practical difficulties of operating to very precisewind strengths, particularly at London City Airport where thesurface wind

is often different at each end of the runway, theoperating company are reviewing the content and presentation ofthe manuals.

The crew used the correct procedure and landed near the end ofthe touchdown area. The touchdown point was corroborated by thecrew and the ATC controller, and the FDR calculations were consistentwith their assessment. The spoilers were deployed correctly andthe commander commenced braking; the aircraft should have stoppedwithin the declared runway. The fact that EI-CMY did not stopuntil the end of the starter extension indicates that the runwaysurface was slippery, or that the braking technique used was incorrector late, or that there was some kind of technical malfunction.

Mu-meter checks of the runway indicated good braking conditionsand previous and subsequent landing aircraft reported no brakingdifficulties. Both crew members were confident that the correctbraking technique was used and, when the retardation was lessthan expected, an alternative hydraulic system was selected; thisimmediately resulted in an improved performance. In fact, thecommander reported that she was then so confident of the brakingperformance that she could have stopped within the declared runwaybut was able to reduce braking slightly to minimise passengerdiscomfort. The crew's account was also strengthened by the factthat an identical malfunction had been reported five days earlier. Following the earlier incident, no defect was found. After thislater incident, minor defects were noted within the braking systembut no fault could be detected which would have caused the reportedsymptoms. However, when the anti-skid control box was replaced,subjective views of the crew who did taxi checks before and afterthe replacement, were that the braking system had improved. Extensivechecking revealed no significant defect with the control box. Nevertheless, the evidence on balance indicates that there wassome sort of technical malfunction which degraded the anti-skidsystem.