Department of Trade

ACCIDENTS INVESTIGATION BRANCH

Boeing 707 Series 436 G-APFK
Report on the accident at Prestwick Airport, Scotland on 17 March 1977

LONDON
HER MAJESTY'S STATIONERY OFFICE

List of Aircraft Accident Reports issued by AIB in 1978

No.	*Short Title*	*Date of publication*
1/78	Bell 206(Jet Ranger) G-BAYA at Loch Avon, Inverness-shire January 1977	May 1978
2/78	Agusta Bell 206BG-AVSN DH 82a (Tiger Moth) G-ANDE at Biggin Hill Aerodrome Kent May 1977	July 1978
3/78	Piper PA E 23 (Aztec) Series 250 G-AYSF at Moffat Dumfriesshire Scotland July 1976	*(forthcoming)*
4/78	British Airways Boeing 747-136 G-AWNA at Bombay Airport November 1975	July 1978
5/78	Brantly Helicopter 305 G-ATLO at Astley Village, Stourport-on-Severn October 1976	August 1978
6/78	Boeing 707 Series 436 G-APFK at Prestwick Airport, Scotland March 1977	

ISBN 0 11 512446 2

Department of Trade
Accidents Investigation Branch
Kingsgate House
66-74 Victoria Street
London SW1E 6SJ

5 September 1978

The Rt Honourable Edmund Dell MP
Secretary of State for Trade

Sir,

I have the honour to submit the report by Mr C.C. Allen, an Inspector of Accidents, on the circumstances of the accident to Boeing 707 G–APFK which occurred at Prestwick Airport, Scotland on 17 March 1977.

I have the honour to be
Sir
Your obedient Servant

W H Tench
Chief Inspector of Accidents

Accidents Investigation Branch

Aircraft Accident Report No. 6/78
(EW/C 591)

Operator:		British Airtours Limited
Aircraft:	*Type:*	Boeing 707
	Model:	Series 436
	Nationality:	United Kingdom
	Registration:	G–APFK
Place of accident:		Prestwick Airport, Scotland Latitude 55° 30'30" North Longitude 04° 35'00" West
Date and time of accident:		17 March 1977 at 0849 hrs. All times in this report are GMT

Synopsis

The accident was notified by Prestwick Air Traffic Control to the Department of Trade on 17 March 1977 and the Accidents Investigation Branch commenced an investigation the same day.

The aircraft was engaged in pilot conversion training. During the take-off rotation phase the commander retarded No. 1 engine to simulate an engine failure. As the aircraft began a divergence to the left the commander took over control from the trainee first officer, but shortly afterwards the No. 1 engine nacelle hit the ground. The aircraft then commenced a violent yaw/roll to the right, lost height, and again struck the ground. It pivoted further to the right and continued tracking sideways down the runway. The landing gear collapsed and all the engines were torn off. The aircraft was destroyed by impact and fire. During the evacuation one of the four crew members was injured. There were no other occupants.

The report concludes that the accident was caused by the loss of control which resulted from a delay in taking full corrective action during a simulated outboard engine failure exercise during take-off.

1. Factual Information

1.1 History of the flight

The accident occurred during the first take-off on the fourth day of a conversion base training programme onto the Boeing 707 - 436 aircraft for two pilots, one a captain and the other a first officer. Both pilots had satisfactorily completed a ground school and simulator course on the aircraft type. During the three days prior to the accident, training in upper and middle airwork had been completed and circuit flying, with touch and go landings, had commenced; night circuit flying had been carried out the previous evening.

On the day of the accident the trainee first officer was in the right hand pilot's seat and was flying the first detail. [1] The commander was in the left hand pilot's seat, and the captain under training was acting as flight engineer, [2] being supervised by the fourth crew member, a supervisory first officer who was seated behind the commander.

After completing all the necessary checks and the engine starting procedure the commander gave the trainee first officer a comprehensive briefing on cross wind take-off techniques with reference to the local weather forecast, which gave a surface wind of 190°/18 knots gusting to 35 knots. In particular he emphasised the need for into-wind aileron, demonstrating the amount required, and for opposite rudder. At 0842 hrs the aircraft was cleared to taxi to Runway 13. While taxying, the 'taxying check list' was completed.

At the light aircraft weights used for training, standardized take-off airspeeds were used as follows: V_1 – 125 knots, V_R – 135 knots and V_2 – 145 knots[3]. Based on the prevailing conditions and actual aircraft take-off weight of 94,580 kg, the true take-off airspeeds were as follows: V_1 – 125 knots, V_R – 125 knots and V_2 – 142 knots; the V_{MCG} and the V_{MCA}[4] were 125 knots and 119 knots respectively.

After receiving ATC clearance, the aircraft entered the active runway from the fast turn-off for Runway 31. From this position the take-off run available was approximately 2,388 metres; the take-off run required was 1,433 metres.

On entering the runway the commander handed over control to the trainee first officer and the aircraft commenced its take-off run, from a rolling start, shortly after 0848 hrs. The Tower passed a surface wind of 220°/15 knots and the trainee applied about 15° to 20° of into-wind aileron (ie right wing down) and some left rudder. Full power was then applied and the V_1 and V_R airspeeds were called by the flight engineer. As the aircraft was being rotated to a pitch attitude of 4½° (flight recorder evidence) [5] the commander simulated a No. 1 engine failure by retarding the appropriate thrust lever, and calling out "number one engine's failed." [6]

After the aircraft became airborne it climbed away in a normal manner to a height of approximately 20 to 30 feet when suddenly the left wing dropped about 20° and the No. 1 engine nacelle struck the left edge of the runway. The aircraft then began to yaw and roll to the right and to sink to the ground. The yaw/roll continued until No. 4 nacelle struck the runway and the aircraft then tracked sideways down the runway, with

---

1 All first officer training was carried out from the right-hand seat.

2 For clarification in this report the captain on conversion training is referred to as the flight engineer, the duty he was fulfilling at the time of the accident.

3 V_1 is the engine failure decision speed, V_R is the rotation speed and V_2 is the take-off safety speed.

4 V_{MCG} is the minimum control speed on the ground with an outboard engine inoperative. V_{MCA} is the minimum control speed in flight with an outboard engine inoperative.

5 The commander's assessment of the pitch attitude attained was 8°.

6 The verbal identification of a failed engine was in accordance with company policy at the time.

the engines and other parts of the structure breaking away and the landing gear collapsing. It came to a stop almost at the intersection of Runway 03/21. The distance from the start of the take-off roll to this point was approximately 2,230 metres.

The commander, in describing the sequence of events, said that the take-off run was nicely controlled in all respects. At V_R he simulated No. 1 engine failure but corrective rudder was not properly applied and a yaw to the left commenced. He immediately took over control and said "I have it". A yaw/roll developed to the left, at the same time the aircraft seemed to maintain height or even make a shallow descent. He also said that in order to arrest the sink rate and correct the roll he immediately restored power on No. 1 engine and reduced thrust on No. 4[1] just before the aircraft sank back onto the ground with the wings almost level. The aircraft then yawed to the right in a flat attitude, skidding sideways.

The trainee first officer recalls rotating the aircraft at V_R and the commander calling that No. 1 engine had failed. He believes that his reaction was to keep the aircraft on a straight flight path but cannot remember his specific control inputs. He recalls being unable to raise the left wing which had dropped, and that as he released the control column to the commander the wheel was hard over to the right wing down position.

The supervisory first officer recalls that just before the aircraft came to a stop he called "throttles" and noticed that three of the thrust levers were forward, without being able to identify which were the three. He could not remember the position of the fourth.

Shortly before the aircraft came to a stop the crew commenced the emergency overrun drills. Subsequent examination confirmed that these had been completed, except that the No. 4 fire handle was found in the 'normal', not pulled, position and the flap lever was at 40° instead of 50°. As the aircraft came to a standstill the commander and first officer opened their respective side windows.

Fire and associated dense black smoke commenced to appear from around the aircraft immediately after the main impact. Fire appliances left their station, situated almost opposite the final crash position, at about the time the aircraft came to rest.

The external fire was rapidly dealt with but the internal fire was not extinguished for some 50 minutes. Details of the fire and fire-fighting activities are given in sub-heading 1.14.

After the aircraft came to rest the four crew members escaped from the burning wreckage via the forward right galley door; the flight engineer broke his foot in the evacuation. The crew were later taken to the airport medical centre (see sub-headings 1.13 and 1.15).

1.2 Injuries to persons

Injuries	Crew	Passengers	Others
Fatal	–	–	–
Serious	1	–	–
Minor/None	3	–	

1.3 Damage to aircraft

The aircraft suffered substantial crash damage and was largely destroyed by the subsequent ground fire.

1.4 Other damage

Three runway light fittings and two VASI units were damaged and the runway surface was badly gouged.

---

1 The flight recorder readout indicates that Nos 3 and 4 engines ran down almost simultaneously (see subheading 1.11).

1.5 Personnel information

(a) Commander (Training Captain)

Age:	48 years
Licence:	Airline Transport Pilot's Licence valid to 18 March 1978
Aircraft ratings:	Aircraft Part 1: Comet IVB, Vanguard, Boeing 707. Instrument rating valid to 9 December 1977
Last medical examination:	11 November 1976, assessed fit, valid to 31 May 1977
Last certificate of test:	Boeing 707, 9 November 1976
Flying experience:	
Total pilot hours:	10,180
Total flying hours on B 707 aircraft:	1,500
Total flying hours as B 707 training captain	315
Total flying hours in last 28 days:	26
Rest period:	10 hours 25 minutes

The commander was appointed to a position as training captain on Vanguard Aircraft with British European Airways in 1968. In 1970 he transferred to British Airtours as a training captain on Comet aircraft and in 1974 he became a training captain on Boeing 707 aircraft.

(b) Co-pilot (trainee first officer)

Age:	29 years
Licence:	Senior Commercial Pilot's Licence valid to 17 June 1979
Aircraft rating:	Aircraft Part 1: PA28 and 32, Vanguard. Instrument rating valid to 9 April 1978
Last medical examination:	30 October 1976, assessed fit, valid to 30 April 1977
Flying experience:	
Total pilot hours:	2,093
Total flying hours on B 707 aircraft:	4 hours 45 minutes dual instruction
Total flying hours in last 28 days:	4 hours 45 minutes
Boeing 707 simulator:	Total 45 hours 40 minutes including 13 hours 35 minutes co-pilot handling

Rest period:	10 hours 25 minutes

The trainee did not fly for a period of 12 months, apart from 35 hours on Vanguard aircraft in November 1976, before he commenced his course on Boeing 707 aircraft in January 1977. The commander, who happened to have been in charge of the last week of his simulator training, recorded the following comment: "A very good standard achieved in final checks at all stations". On the day before the accident, during the conversion training on the aircraft, under the same training captain, the trainee carried out about seven simulated outboard engine failures on take-off after V_1 without incident. Following this flying detail the commander commented in the training records "Circuit work on 4 and 3 engines – progress is steady – night flying completed, no problems".

(c) Other crew

The two other crew members were a captain, also on conversion training, who was fulfilling the flight engineer's duties, and a supervisory first officer. The licences of both these pilots were in order.

1.6 Aircraft information

1.6.1 General particulars

Type:	Boeing 707–436
Manufacturer:	Boeing Airplane Company, USA
Date of manufacture:	1960
Engines:	4 Rolls-Royce Conway Mark 508 (R.Co-12) each giving 17,500 lb guaranteed minimum thrust.
Certification:	(a) Certificated in the Transport (Passenger) Category; its certificate of airworthiness was last renewed on 6 December 1974 and was valid for four years.
	(b) A certificate of maintenance was issued after a Service 12 check on 5 February 1977 which was valid for 500 hours or three months.
Hours flown:	The airframe had flown 53,180 hours since new and 79 hours since its last periodic check. The engines had completed the following hours since overhaul:

1	2	3	4
7,557	2,607	5,599	4,743

Fuel:

At take-off the aircraft's wing tanks contained 33,960 kg of JP1 (Avtur); a very small amount of fuel was present in the centre-section tank, and the auxiliary tanks were empty.

Weight:

Maximum certificated take-off weight:	141,400 kg
Take-off weight:	94,580 kg
Centre of gravity range:	19% to 35% SMC
Centre of gravity position:	28% SMC.

The aircraft was fitted with a parallel type yaw damper in the rudder system which was switched off, as it was required to be, for take-off. It is considered that this factor, and the type of yaw damper involved, had no bearing on the cause of the accident.

For training purposes, the flight deck door had been removed in order to stop it banging and to allow quick access to the cabin. British Airtours have now revised this procedure. They consider that in the event of an emergency involving smoke, the importance of eliminating a possible airflow through the aircraft, by keeping the flight deck door closed, outweighs the problem of the door becoming jammed. Consequently the door is no longer removed on training flights.

1.6.2 *Escape exits and aids.*

Both main passenger doors and both galley doors were equipped with inflatable escape slides installed in the doors. During normal operation, after each door has been closed, its respective slide is connected to the aircraft by a hook which is manually engaged onto a 'D' ring hinged in the cabin floor at each door position. If an emergency occurs, normal outward opening of the door will cause the hook to pull the end of the escape slide, drawing it out of its container on the inside of the door. It then falls completely clear of the container and hangs over the door sill, remaining attached to the aircraft only by engagement of the hook with the 'D' ring in the floor. Inflation of the slide is then carried out by manual operation of a lanyard. For normal opening of the door the hook is disengaged from the 'D' ring and supported clear of the floor by an attachment on the inside of the door. Retention of the hook on the 'D' ring is normally achieved by means of a locking shroud which closes the gap in the hook through which the 'D' ring slides during engagement and disengagement.

1.7 Meteorological information

Weather forecasts prepared by Prestwick Meteorological Office were available for crews at the Prestwick British Airways Training Centre used by British Airtours.

The forecast covering the area within 10 kilometres radius of Prestwick for the period from 0600 hrs to 1500 hrs on 17 March included the following:

Surface wind:	190°/18 knots occasionally gusting to 35 knots
Cloud:	2/8 cumulus at 2,000 feet occasionally 6/8 cumulus/cumulonimbus at 1,200 feet
Visibility:	Over 10 kilometres occasionally 6 kilometres in showers.

The following observation was made at Prestwick Airport at 0850 hrs:

Surface wind:	Variable 180° – 250°/minimum 9 knots maximum 31 knots mean speed 210°/17 knots

Visibility:	18 kilometres
Cloud:	1/8 800 feet 2/8 cumulonimbus 1,400 feet 5/8 4,000 feet
Temperature:	+7° centigrade
Dewpoint:	+6° centigrade
QNH:	996 millibars
QFE:	993.9 millibars

The natural light conditions were full daylight.

The airfield data obtained by the trainee prior to start-up gave the surface wind as 210°/15 to 25 knots, occasionally 30 knots. Surface winds passed to aircraft in the circuit by Prestwick Tower during the 30 minutes prior to the accident ranged between 190° – 230°/15 – 24 knots. The surface wind passed by the Tower as the aircraft began its take-off run was 220°/15 knots.

The operator's cross wind limit for first officer handling on take-off was 15 knots.

On the day prior to the accident, whilst the trainee was engaged in circuit work, the surface wind had been across the active runway (13), averaging 140° – 190°/8 – 12 knots.

1.8 Aids to navigation

Not applicable.

1.9 Communications

The VHF radio communications between Prestwick Tower and the aircraft were normal. Following take-off clearance by the Tower the last message from the aircraft was "Kilo rolling".

1.10 Aerodrome and ground facilities (see Appendix 1)

Prestwick Airport, Ayrshire, Scotland is at an elevation of 66 feet and has two runways 03/21 and 13/31. The latter runway, on which the aircraft was taking-off towards the southeast, was of concrete/asphalt construction, 2,987 metres long and 46 metres wide with paved shoulders which extended 23 metres beyond each side.

Because of work in progress on part of the taxiway leading to the runway threshold, aircraft entered the runway from the high speed turn-off for Runway 31. Some aircraft, including G–APFK, were able to commence their take-off from this position, approximately 2,388 metres of the runway being available.

The runway surface was wet at the time of the accident following the passage of a heavy rain shower.

1.11 Flight recorder (see Appendix 2a)

1.11.1 The aircraft was equipped with an Epsylon EFDAS A1 digital flight data recorder (DFDR) and a Fairchild A100 cockpit voice recorder (CVR). The DFDR was mounted in the tail cone aft of the rear pressure bulkhead and was undamaged. The CVR was mounted forward of the rear pressure bulkhead and had been damaged by fire. However the protected recording medium was undamaged.

The DFDR recorded the following parameters:

Pressure height	Wing flap position
Airspeed	Normal acceleration ('g')
Pitch attitude	N_2 percentage rpm for engines 1, 2, 3 and 4
Roll angle	N_1 percentage rpm for engines 1 and 2
Heading (degrees magnetic)	

GMT was recorded once per second

1.11.2 *Accuracy of data*

The readout of the DFDR showed that invalid data was recorded in the initial part of the take-off. Seven seconds prior to rotation the fault cleared and valid data was obtained from that time until the end of the recording. It was found that the DFDR had been subject to an intermittent fault during previous flights; subsequent checking of the system components by the operator failed to reproduce, or establish the cause of, the fault.

After calibration corrections the accuracy of the recorded data was established as:

Pressure height:	± 50 feet	Heading	± 1°
Airspeed:	± 4 knots	Acceleration	± 0.01g
Pitch:	± 2°	Engine rpm	± 4%
Roll:	± 2°		

1.11.3 *Handling and performance evaluation*

Critical handling aspects and the associated aircraft responses were examined using evidence from the DFDR and the manufacturer's stability derivatives * for the type (see Appendix 2). The following deductions were drawn:

(a) The take-off proceeded normally until shortly after the commencement of rotation, when the No. 1 engine thrust lever was retarded to simulate engine failure.

(b) One second after No. 1 engine N_1 rpm started to decrease, it had fallen to 80%, and the majority of the thrust would have been lost. This indicates a fairly rapid rate of closure of the thrust lever.

(c) The resultant rapid yaw to the left was not initially counteracted. There was no control movement of significant amplitude and duration until the point at about – 5 seconds, (ie 5 seconds before the main impact), about 2 seconds after the simulated engine failure, when full right rudder was applied.

* Stability derivatives are the coefficients, such as rolling moment due to sideslip, which relate the forces and moments on an aircraft at any instant to its motion at that instant.

(d) Similarly there was no appreciable lateral control movement until at the earliest about – 3 seconds, just before the No. 1 engine nacelle touched the runway. However since the impact was responsible for a large roll acceleration input, the exact time of aileron/spoiler actuation cannot be determined. Certainly full aileron and spoiler were being used during the period of flight after the first impact, so that they could have been applied as late as about – 2 seconds.

(e) The recovery from the initial yaw to the left and the subsequent final yaw to the right is consistent with full right rudder, full lateral control, the restoration of thrust on No. 1 engine, and no thrust from Nos 3 and 4 engines.

(f) The question whether simply restoring thrust on No. 1 engine without alteration of Nos 3 and 4, would have been sufficient to effect a recovery is difficult to answer. It would have been several seconds before the thrust became effective and it is probable that in that period the aircraft would have gone irretrievably out of control. It was already at a large angle of sideslip and the rudder efficiency must have been on the verge of falling to near zero, in which case there would have been no chance of recovery.

(g) Had the thrust on No. 4 engine, only, been reduced following the restoration of thrust to No. 1 engine, the chance of recovery would have been slightly better than with Nos 3 and 4 engines both reduced. However unless full rudder and lateral control had been applied early enough to prevent the No. 1 engine nacelle hitting the runway in the first instance, it seems probable that the accident could not have been avoided.

(h) The above evaluation of the data is consistent with an initial rotation at a normal rate to about 4½^0 recorded pitch attitude. Had the rotation been continued to a rather larger angle – for example 8^0 would be an appropriate attitude for an established climb a few seconds after unstick, instead of the recorded reduction in pitch to about 3^0 – the course of the flight could have been different. Then given that full lateral control was not applied until about – 3 seconds it is unlikely that even with the extra height gained by the larger pitch angle, the wing could have been prevented from striking the ground. Under these different circumstances the impact would have been at the tip and not on the nacelle and at an appreciably greater bank angle.

(i) Within the expected limits of accuracy, calculations indicate that, at least until No. 1 engine nacelle struck the ground, the flight path was consistent with:

1. The control inputs mentioned above
2. The reduction in thrust following the simulated No. 1 engine failure
3. The large increase in drag due to sideslip.

1.11.4 *Cockpit voice recorder (CVR)*

A transcript of the CVR was made; the 30 minute duration of the recording covers the whole of the crew's conversation and radio-telephony on the day of the accident, from after engine start to the final call by the commander at – 1½ seconds of "I have it". The recording also covers the final portion of the crew's previous day's flying detail.

Intercom was used by the crew at all times and the recording confirmed all the points made by the crew concerning pre-flight briefing, drills following an in-flight engine failure and discussion of handling techniques relevant to cross wind conditions. In addition, the recording of part of the previous day's flying confirmed that progress by the two trainees had been satisfactory and that the training detail was conducted in a professional and competent manner.

1.12 Examination of the wreckage

1.12.1 The aircraft (see Appendix 3)

Examination of the wreckage and of marks on the runway showed that the aircraft had initially struck the left edge of Runway 13 with the underside of the No. 1 engine nacelle at a point 895 metres from the up wind threshold, ie approximately 1,493 metres from the commencement of the take-off point, and at an elevation of 52 feet. The No. 1 nacelle remained in contact with the runway hard shoulder for a distance of approximately 50 metres during which the mounting structure deflected upwards sufficiently to break the diagonal brace and wrinkle the skin of the pylon. Subsequently the aircraft struck the left hard shoulder of the runway, at a point 200 metres beyond the initial impact, with the underside of the No. 4 nacelle. The aircraft continued to slide along the hard shoulder during which time the Nos 3 and 4 engine nacelles and the two nose wheels broke away.

The nose gear strut (minus its wheels) dug a groove into the runway and the aircraft continued to slide parallel to the runway and to turn to the right until the fuselage was at approximately 90° to the runway direction. The direction of slide then changed and the aircraft gradually re-crossed the runway towards the right side. At a point approximately 550 metres from the initial impact, it rolled rapidly to the left striking Nos 1 and 2 nacelles heavily against the runway, and causing them both to separate from the airframe. The left main gear then failed inboard and the Nos 1 and 2 engines rolled under the left wing, penetrating Nos 1 and 2 main fuel tanks respectively. As the aircraft slid towards its left, fuel, escaping from the No. 1 tank, ignited immediately as a result of contact with the hot components of the No. 1 engine and a trail of flame followed the aircraft as it progressed down the runway. The aircraft gradually turned back towards the runway heading, during which time the centre and rear fuselage sections and the inboard part of the left wing passed over this burning fuel. The aircraft finally came to rest 735 metres from the initial impact point, orientated approximately 60° right of the runway heading. At some stage during the sideways ground slide, the right main gear failed outwards.

The fuselage suffered an external split on the right side running from the wheel-bay upwards to the aircraft centre-line. The keel beam, aft of the wing box, had been destroyed by the sideways and inwards failure of the left main gear and a section of pressurized floor above the right wheel bay had been torn out by the outward failure of the right main gear. The removal of this section produced a hole leading from the right wheel bay into the cabin (see Appendix 4). The wing centre section and its fuel tank had remained intact and free from fire damage.

1.12.2 Flying Controls

All flying controls and their associated systems were examined, extensively tested, and found to be fully serviceable, with the exception of hydraulic pipework for the utility and auxiliary systems damaged by the collapse of the landing gear.

1.12.3 Engines

1.12.3.1 General

From initial examination of all four engines it was not possible to establish their power output at the time of the impact. Since certain discrepancies were apparent between the DFDR evidence of No. 3 engine power and crew recollection of thrust lever position, it was decided to carry out a strip examination of the engine. No evidence was found of pre-impact failure within the engine, which showed signs of considerable rotational energy at impact. This does not necessarily indicate a condition of high power. However, it was not possible to establish from the engine damage whether high or low power was present when it separated from the aircraft.

1.12.3.2 Engine control system

The engine thrust lever systems were examined in detail. In each case the tension occurring in the operating cables when the engine nacelles separated from the aircraft caused them to spring back until the turnbuckles jammed in the pulley-blocks within the leading edges of both wings. Consequently, there were no reliable indications to be found of the pre-impact positions of any of the thrust lever controls. Similarly the angular positions of the pulleys on the fuel control units gave no reliable indications of pre-impact engine power settings. However, correct operation of the thrust levers and the intact sections of the throttle cables was confirmed. There was complete freedom and independence of operation between each of the four thrust lever controls, and the friction control functioned effectively.

1.12.4 Fuel system

Although Nos 1, 2 and 3 fire handles were found in the 'pulled' position and all engine fuel shut-off valve switches were in the 'off' position, only Nos 2 and 3 shut off valves were found to be closed. Tests on Nos 1 and 4 shut-off valves indicated that they were serviceable. Damage to the area of the looms supplying Nos 1 and 4 shut-off valves was sufficient to account for failure of operation of these valves if the fire handles were not operated until after the respective engines had separated. There was insufficient evidence to confirm whether or not the No. 4 handle was operated. In the event, the failure of operation of Nos 1 and 4 shut-off valves had no bearing on the development of the fire.

In view of the conflicting evidence concerning No. 3 engine, the No. 3 fuel tank and system was examined in detail. No evidence of any defect could be found. Analysis of a sample of fuel taken from the undamaged No. 3 tank showed that it conformed to the specification of JP1 (Avtur).

1.12.5 Pitot static systems

Nos 1 and 2 pitot static systems were leak checked and found to be well within specification. The two airspeed indicators were calibration checked after removal. The No. 1 unit was found to under-read by 2 – 3 knots at the 150 knot point and the No. 2 unit was within calibration from 120 knots to 220 knots. The specification called for a maximum tolerance of ± 2.5 knots in the 150 knot to 180 knot range.

1.12.6 Escape slide

During the accident, the crew escaped via the forward galley door, but the slide did not operate correctly. On examination it was found to be still in its housing on the door, with the engagement hook hanging loose. Further information relating to tests of the escape slide is at paragraph 1.17.4.

1.13 Medical and pathological information

1.13.1 Ambulance services at Prestwick Airport

According to Section VII, Medical Services, of CAP 168, Licensing of Aerodromes, issued by the Civil Aviation Authority, there was no requirement for an ambulance to be stationed at Prestwick Airport, as ambulances from an outside source could arrive at the aerodrome within 15 minutes of being summoned. A full ambulance service was available at Ayr (approximately 1½ miles away). In the event of an accident on the airport, the procedure is that the airport police establish an incident post at the crash location and request ambulance units. On arrival at the airport the ambulances are held at the Police Office, near the main terminal building, and then are escorted by a police mobile unit to the scene of the accident as required.

When the accident occurred this procedure was followed. Two ambulances from the Scottish Ambulance Service at Ayr arrived at the Police Office and at 0902 hrs one of these proceeded to the accident site. However, by the time it arrived, the crew had left in an airport vehicle for the medical centre in the airport terminal building. Later, when this ambulance took the injured flight engineer to hospital, it was delayed for a short time at one of the airport security gates, before clearance was obtained for it to proceed.

1.13.2 *Treatment of the crew at the medical centres*

When the crew arrived at the airport terminal building the injured crew member was carried by his colleagues to the medical centre on the first floor. On meeting the medical staff the crew were asked what had happened, the medical centre being unaware that an aircraft accident (as distinct from a 'full emergency') had occurred (see paragraph 1.17.5 for further information relating to initial emergency procedures at Prestwick). The crew were seen by the doctor on duty, refreshment and blankets were made available, and washing facilities provided for the commander, the trainee first officer and for the supervisory first officer who was badly contaminated with kerosene. The injured flight engineer, after partially stripping himself of his kerosene soaked clothing, was wiped down. He was then, without being washed, sent by ambulance to a local hospital for treatment. At the hospital his foot was X-rayed, found to be broken, and set in plaster without any further cleansing.

1.13.3 *Expert medical opinion and follow-up action*

According to expert medical opinion, contamination of the body by kerosene, if left untreated, is likely to cause defatting and drying of the skin, resulting in severe irritation. The remedy is to strip off all contaminated clothing and wash the affected areas with copious quantities of cold water.

Shortly after the accident the British Airports Authority advised airport medical officers of the need for early treatment of people contaminated with fuel. They have also constructed a shower room at the medical centre at Prestwick Airport.

In November 1977 the CAA issued Information Circular No. 111/77, warning operators and aerodrome managements of the dangers associated with fuel contamination and the need for immediate first aid treatment of such cases.

1.14 Fire

1.14.1 *Description*

Fire commenced during the ground slide (see paragraph 1.12.1 above). When the aircraft was sliding to the left, the burning fuel from the No. 1 tank flowed inboard and slightly aft relative to the airframe, causing severe burning to the underside of the left wing and flaps and to the left side of the rear fuselage. After the aircraft came to a stop the burning fuel formed an intense fire area under the rear part of the left wheel bay. It appears that initially the opening of the flight deck side windows combined with the absence of the flight-deck door allowed an unimpeded flow of air between the cabin and the side windows. This, together with the opening of the forward galley door, provided outlets which allowed smoke and flames to be drawn through the disrupted keel beam into the right wheel bay and then upwards through the hole in the pressure floor and into the cabin (see Appendix 4). The 'chimney' effect caused this fire to burn rapidly through the top of the fuselage at a point over the wing centre section, and from the centre section the intense fire ignited the cabin furnishings and spread quickly forward. Most seats and all the trim in the forward part of the cabin were destroyed, and fire damage was also evident in the flight deck.

A feature of the interior fire was the rapidity with which the whole of the cabin was filled with intense black smoke and acrid fumes which reduced the visibility inside the aircraft to almost zero. The crew took about one minute to evacuate the aircraft after it had come to rest, by which time the smoke had not reached the forward galley door. However, immediately following the evacuation, the whole of the forward cabin and flight deck was filled with dense black smoke which was seen pouring out of the open flight deck windows.

1.14.2 *Fire fighting details*

The main fire station at Prestwick is situated on the north side of runway 13/31 very near to the position where the aircraft came to rest (see Appendix 3). There is also a sub fire station at the other end of the airport. The alarm was passed immediately by Air Traffic Control to the fire service and in addition the accident was seen from both fire stations. All the airport's fire vehicles were immediately dispatched to the scene. The vehicles had to make a detour on to the grass around the trail of burning fuel on the runway, but apart from this no other difficulties were experienced in reaching the aircraft. The first vehicles from the main fire station were in position ready to fight the fire approximately one minute after the accident had occurred. The fire officers quickly established from the four crew members, who had already safely left the aircraft, that no one else remained on board, and they were therefore able to concentrate on fighting the fire, which was by this time burning fiercely.

Six vehicles from the airport fire service attended the fire; three foam tender pumps, two carbon dioxide tenders and a rescue tender. A rapid intervention vehicle, which was not part of the fire service complement at the time of the accident, was later brought into use when the main foam tender pumps were being replenished. These vehicles were manned by fifteen firemen under the command of the senior airport fire officer. Five additional appliances, four water tenders and a breathing apparatus van together with twenty-five firemen were supplied from various stations by the local authority fire service and arrived at the scene of the accident between 9 and 16 minutes after the alarm was given.

Foam tender pumps were positioned one on either side of the fuselage, forward and upwind of the mainplanes. Monitors were used to attack the fire, working outwards from the wing roots to the wing tips. The third foam tender pump joined in the attack on the left side of the aircraft where the fire was fiercest. Hand lines were used to combat a persistent fire under the left hand side of the fuselage just behind the main wing junction. It is estimated that the external fire was contained and extinguished within approximately 4 minutes of the time the aircraft came to rest.

The internal cabin fire proved very difficult to extinguish. The firemen had first to control the external fire before being able to approach the fuselage, by which time the cabin was filled with smoke and fumes. Water was poured into the cabin through windows over the mid-wing position in order to combat the fire in that area and prevent the centre fuel tank from igniting. Firemen entered the cabin through the forward galley door but were hampered by the poor visibility and the heat coming from the region of the flight deck. The use of carbon dioxide had little effect on the fire as the heat and airflow through the cabin exhausted the carbon dioxide, along with the other gases, out through the doorway. Eventually two diffuser jets were placed in the galley and another through the left flight deck window. The internal fire was eventually brought under control after about 40 minutes and extinguished some 12 minutes later.

The internal fire fighting was reported to have been physically very demanding, due to smoke and acrid fumes affecting respiration and to very poor visibility. The use of breathing apparatus proved to be very effective in helping the firemen overcome the effects of the smoke and hot gases.

Fluoro-protein foam was the main agent used to control the external fire, while large quantities of water were used inside the cabin. Two foam tender pumps exhausted their supplies dealing with the external fire but the third foam tender pump, backed up by appliances from the local authority fire service, continued to fight the internal fire with water taken from the airfield hydrants. 455 gallons of fluoro-protein foam were used, together with 1,320 lb of carbon dioxide and an unknown quantity of water, in excess of 10,000 gallons.

Information on the flame resistance standards of the cabin interior furnishing materials is given at paragraph 1.17.3.

1.15 Survival aspects

When the commander opened his side window he saw an intense fire in the left wing. Deducing that the main damage was on the left side, he ordered an evacuation from the right. The two pilots and the flight engineer had been wearing full inertia-reel type shoulder harnesses and the supervisory first officer the lap strap provided. All four crew members were uninjured and had no difficulty in leaving their seats.

The flight engineer went direct to the forward right galley door and opened it. However, the escape slide which had been attached to its 'D' ring in the floor prior to taxying out, did not deploy. Because thick black acrid smoke was penetrating the forward compartment, the crew decided to jump from the door sill, which was approximately nine feet above ground level. After the supervisory first officer and flight engineer had jumped, the commander and co-pilot swung by their hands from the sill and dropped to the ground, into a pool of kerosene approximately three inches deep. All landed safely, apart from the flight engineer who landed badly, broke his foot and fell back into the kerosene. He and the supervisory first officer were badly contaminated. All the crew were out of the aircraft approximately one minute after it came to rest. Because they were in their shirt sleeves in a keen wind and suffering from shock, they began to feel the effects of exposure. They therefore took shelter in one of the airport vehicles which had arrived at the crash scene. About twelve minutes after the accident, as no ambulance could be seen, this vehicle took them to the airport medical centre.

1.16 Tests and research

For certification purposes, under both United Kingdom and United States airworthiness regulations, the minimum control speed in flight, V_{MCA}, is established with 5^{0} of favourable bank (ie towards the live engine(s)). During the course of the investigation the Civil Aviation Authority (CAA) carried out tests on a Boeing 707–436 which demonstrated the variation of V_{MCA} with bank angle. The results, with which the manufacturer does not disagree, are given at Appendix 5. They show that variation of V_{MCA} over the range from 0^{0} to 7^{0} of favourable bank is non-linear, increasing at a progressively greater rate as bank angle is reduced towards the wings level attitude.

The aircraft's certificated V_{MCA} under the accident conditions was 119 knots; the test results indicate that the V_{MCA} with wings level would therefore have been about 160 knots.

1.17 Additional information

1.17.1 Aircraft handling and training considerations

The Airworthiness Division of the Civil Aviation Authority have provided the following information regarding the handling characteristics of the Boeing 707–436:

> "In the event of an outer engine failure on take-off at speeds of V_1 and above, the aircraft will diverge in heading and if airborne will roll. It is the most demanding of the first generation jet transport aircraft in this manoeuvre not only for its fairly

marked roll with sideslip but also for its unusually small roll angle clearance on or close to the ground before a pod may scrape the surface. The yaw and roll divergences will increase rapidly unless control is imposed within the accepted period of 1 to 1½ seconds. The required forces are fairly high and the controls generally lack precision over small angles."

Regarding the variation of V_{MCA} with angle of bank (see Appendix 5) the CAA comment:

"It should not be deduced that if the aeroplane is to the left of the curve – say wings level at 140 knots – that control is necessarily lost. The heading will of course be changing but the pilot will have something like another half lateral control range available with which to roll the aircraft to a bank angle at which he re-establishes full control including the ability to maintain heading. An aeroplane is not 'out of control' until all the available rudder and lateral control is used up: as the mean lateral control angle in the tests was around 1/3 to ½ there clearly remained much more available."

"The increase of V_{MCA} with decreasing bank angle on a 707–436 is larger than is usually the case on more modern types with power-operated controls because the rudder, being only 'boosted' and not fully powered, will blow back at increasing airspeeds."

The following general information and advice on simulated engine failure training on take-off in cross wind conditions has also been provided by the CAA:

"For United Kingdom certification V_{MCG} is established in a 7 knot cross wind component from the adverse side, the 'trade' for higher values varies considerably between types – a good conservative rule of thumb is to add 1.3 knots to V_{MCG} for every 1 knot of cross wind component in excess of 7 knots, up to a maximum component of 15 knots at normal training weights around maximum landing weight. Further extrapolation is not advised, because the greatly increased V_1 will then be incompatible with the V_R and V_2 speeds. The reciprocal use of this rule of thumb (ie reducing V_{MCG}) for an intended cut of a down wind engine is not permitted because the performance of the aircraft is not scheduled for any cut speed lower than the Flight Manual value. The 15 knot 'limit' would lift V_{MCG} by 11 knots making, in the case of the Boeing 707–436, a value of 136 knots.

The CAA also mention that, in the case of an instructor intending to cut a down wind engine, the aircraft will be quite controllable in very strong cross wind components. There are however penalties in this practice, the one relevant to this accident being that the rudder angle required during the ground roll will be different to that required after the engine cut and will change markedly after lift-off.

1.17.2 *British Airtours follow-up action*

Following the accident British Airtours re-examined their training programme for simulated engine failure on take-off and gave revised instructions to their training captains with particular reference to:

1 Cross wind limitations

2 Standardized take-off airspeeds

3 Timing of failure

4 Identification of failed engine

5 Rate of power reduction.

1.17.3 *Flame-resistance standards of interior furnishing materials*

The materials used for furnishing the interior of the Boeing 707–436 were certificated in the United States of America to the American CAM 4 (b) regulations. These required that all materials were at least flash-resistant and that wall and ceiling panels, the covering of upholstery, and floors and furnishings should be flame resistant. These standards were implicitly accepted by the Air Registration Board (ARB – now part of the CAA) when the aircraft type received its UK certification. The interior of G–APFK was subsequently refurbished with materials which complied with ARB Specification No. 8 Issue 1. This stated that the furnishing materials used in civil aircraft, either inherently or by virtue of their mode of application or size, should not be of such a nature that accidental contact with lighted matches, cigarettes, or local heating due to electric short circuits or lightning strikes, would lead to propagation of fire which could prejudice safe operation of the aircraft. Various tests were laid down to ensure that the material met the specification. The type of flame to which the material was exposed was either a lighted match or petrol lighter or else a small quantity of burning absolute alcohol or methylated spirit.

1.17.4 *Escape slides – tests and follow-up action*

Following the accident, functional testing of the escape slide on the forward galley door was carried out with the escape slide hook engaged onto the 'D' ring. It resulted in the hook becoming disengaged during the initial part of the door opening cycle. The geometry of the door is such that it initially opens inwards, then rotates through a considerable angle about a vertical axis, before moving outwards from the fuselage side. This complex movement caused complete slackening of the hook, followed by sufficient rotation for it to disengage from the 'D' ring before the outward movement of the door pulled the hook away from the 'D' ring. It was established that the gap between the retaining shroud and the tip of the hook was considerably in excess of 0.1 inches, the maximum gap permitted for this component.

Examination of hooks on the remaining three slides in the aircraft showed there was an excessive gap between the shroud and the hook on the rear passenger door unit and a very weak spring on the shroud of the rear galley door hook. Prior to the accident, the hook assemblies were not routinely inspected at the same time as the slides but were normally taken off during changes of the slides and reinstalled upon their replacement. No inspection requirements relating to the hooks were included in the aircraft maintenance schedule, so it followed that unless the hook assemblies had been noted in technical log entries or otherwise found to be defective, there would have been no cause to change them. It is probable, therefore that the hook in question had been on the aircraft for many years and had deteriorated with use.

As a result of the failure, British Airways issued a special check calling for a fleet campaign of functional checks on all slides of this and similar design. In addition a service bulletin was issued calling for a dimensional examination of the hooks, and a functional check.

Subsequently an improved hook was developed embodying a shroud fully overlapping the tip of the hook plate when closed. It also included a strengthened spring on the shroud. The incorporation of the new hook design on all slides of this type on Boeing 707/720 series aircraft has been classified as mandatory by the CAA and compliance was required by March 1978. The new hook design must be used to replace all previous hooks where this type of slide is installed.

1.17.5 *Initial emergency procedures – Prestwick Airport*

The British Airport Authority's airport emergency orders detailed the procedures to be followed when an emergency situation arose. One of the procedures covered the case where an aircraft accident had occurred and another dealt with the situation where an aircraft in flight was in trouble and there was a risk of an accident. In the former case one of the actions of Air Traffic Control (ATC) was to call the Prestwick Airport telephone exchange (PABX) on the direct emergency telephone line and pass details of the accident, prefacing the message with "aircraft accident at ....". In the latter case the action of ATC was similar except that the preface to the message was "full emergency". At the PABX the call illuminated a red light and activated a buzzer. The first telephonist to plug into the emergency line then became the person responsible for receiving the message passed by ATC and in turn passed the information to those services listed in the relevant orders; one of these services was, in both eventualities, the airport medical centre. The action which was to be followed by the medical centre depended on the type of emergency. On receipt of an "aircraft accident" message the Port Health rooms on the ground floor of the terminal building were to be opened as a casualty clearing station, and if necessary medical staff were to proceed to the scene of the accident. In the event of a "full emergency", staff were to stand-by until cancellation or upgrading of the emergency.

When the accident occurred the ATC supervisor was downstairs in the approach control room and was alerted to the situation by the shouts of his colleagues in the visual control room. He ran to his desk and immediately called the PABX on the direct emergency line. He stated that he told the PABX operator "aircraft accident at ...." and then read out his message.

When the alarm sounded at the PABX one of the telephonists plugged into the emergency line and wrote down the message passed to her by the ATC supervisor which, she said, began "emergency, 707 on 31 threshold". The telephone supervisor went across to the telephonist handling the call and collected the two check list pads, one, 'aircraft accident' and the other 'full emergency'.

Since the supervisor had not heard the message herself she asked the telephonist which type of message had been passed so that she could hand her the appropriate check list pad. For confirmation the telephonist called the normal ATC number and was told by a female voice in reply to her query that it was a full emergency. She told her supervisor, who then handed her the "full emergency" check list pad with the result that the services on the PABX distribution list (which included the medical centre) were told "full emergency".

The only female in the ATC control room at the time of the accident was an ATC assistant who acted on the supervisor's instructions. She answered a number of incoming telephone calls when the other controllers were busy but could not recall passing any message to the PABX telephonist.

The alerting system in use at the time of the accident has now been superseded by an omni-crash circuit which enables Prestwick ATC to alert and relay messages concerning an aircraft accident simultaneously to the services involved.

2. Analysis

2.1 Introduction

The post accident examination of the aircraft, its engines, flight controls and systems which survived the disintegration and ground fire revealed no evidence to suggest any pre-crash defects. An evaluation of the aircraft's performance disclosed no indication of excessive drag or loss of thrust apart from that occasioned by the manoeuvres of the aircraft and the rundown of the engines as detailed in paragraph 1.11.3. and Appendix 2b. To attempt to explain the underlying causes of the accident it is therefore necessary to examine in some detail the way in which the aircraft was handled during the brief take-off period, and its associated handling characteristics.

2.2 Co-pilot handling

There is no doubt that the Boeing 707 is a most demanding aircraft to control in the event of an outboard engine failure on take-off at or just above V_1, and that corrective action has to be quick - within a maximum of 1½ seconds from the time the thrust loss starts to take effect and the aircraft starts to yaw towards the 'dead' engine. In the case of the trainee first officer, the majority of his previous experience had been on Vanguard aircraft, a less critical type in this respect. Furthermore, having flown only 35 hours in the previous 12 months, he could not be considered to have been in full flying practice at the commencement of his conversion course. Nevertheless he had been progressing very satisfactorily during both his simulator and aircraft training and had successfully completed about seven of the relevant exercises the previous day, albeit in cross wind conditions less demanding than those present at the time of the accident.

Since the simulated engine failure was on the downwind engine and in fact did not occur until just after rotation, controllability on the ground was not a limiting factor. However, during the take-off run the gusty conditions undoubtedly required considerable effort on the part of the trainee to maintain the aircraft on the runway centre line. Nevertheless, the aircraft's take-off cross wind characteristics had been adequately discussed prior to taxying out, and the ground roll phase would appear to have been well conducted despite the difficult conditions.

Following the simulated No. 1 engine failure as the aircraft became airborne, the correct procedure in this instance should have been to apply full rudder in the opposite direction to that which had been used during the ground roll, while still maintaining or increasing the amount of into-wind aileron in order firstly to prevent any tendency for the left wing to drop and subsequently to bank the aircraft towards the live engines as required to maintain directional control. The evidence suggests that the trainee took neither of these actions in time, so that the commander had to assume control. Bearing in mind that this was the trainee's first take-off of the day, a simulated emergency during the critical rotation phase, following concentration on the ground run in gusty cross wind conditions probably extended his capabilities to the practical limit. The gusty conditions may also have obscured the initial yawing effect caused by the failed engine, leading to a brief moment of indecision. It is customary amongst a number of operators not to simulate emergencies on the first take-off of certain training details, in order to allow relatively inexperienced trainees to 'settle down' on the aircraft by flying a normal circuit before presenting them with additional problems. This would seem a commendable practice, although in view of all the factors involved, each individual case needs to be considered on its merits. It would also appear prudent in the case of an inexperienced trainee, not to simulate a failure during the rotation phase, when the handling pilot's workload is at its highest.

Another factor which may have served to confuse the trainee at the critical moment was the action of the commander (following standard company training procedure at the time) in verbally identifying the failed engine shortly after he retarded the thrust lever. Standard training practice with some operators is only to make the call 'engine failure', leaving it to the trainee to maintain directional control by applying rudder in response to yaw indications, ie in the natural sense. Only at a later stage is the engine identified in order to carry out the required emergency drill.

2.3 The commander's role

The commander's decision to commence the take-off run from the fast turn-off intersection rather than the beginning of the runway was fully justified in the prevailing circumstances and this decision had no bearing on the accident.

The soundness of his decision to persevere with first officer circuit training when the cross wind was known to be fluctuating about the operator's limiting value for this work could be considered marginal, but an understandable one in view of the trainee's previous satisfactory progress in similar, though somewhat less demanding, conditions. However, in the light of this accident it would seem prudent for all operators to examine their cross wind limitations for this type of training, particularly in fluctuating wind conditions.

The flight recorder readout shows that as the aircraft was being rotated the major part of the thrust loss of the simulated failed engine took effect within a period of about 1 second. This indicates a fairly fast rate of closure of the thrust lever, which was in keeping with company policy at the time. A more gradual closure, of about 2 seconds duration, to approximately 75% N_2 rpm, would give the degree of thrust loss required for effective failure simulation whilst insuring that power can be quickly restored in the event of possible loss of control.

Another feature of the rotation phase was the marked discrepancy between the commander's recollection of the pitch attitude achieved, 8°, and the flight recorder readout evidence, 4.6°. Even allowing for the maximum error of +2° the readout figure would only be 6.6°, still 1.4° short of the commander's assessment. However evaluation of the aircraft's performance confirms that the rate of rotation, which was initially normal, ceased at a pitch attitude of 4½° and that pitch was then reduced to about 3°. This could have been due to an instinctive reaction by the trainee on sensing the sudden loss of thrust. The evaluation also confirms that it was because of this low pitch attitude combined with the effect of the excessive sideslip, that the aircraft did not gain any further height. This was probably fortunate, because if the aircraft had continued to climb, a larger angle of bank would have resulted and the initial impact would have been on the left wing tip instead of the engine nacelle, possibly causing a more serious accident than that which occurred.

The commander was a well experienced training captain and was thoroughly familiar with the aircraft's demanding handling characteristics during the critical engine failure on take-off procedure. However, it must be concluded from all the available evidence that on this occasion full recovery action was not taken until just too late. There is an understandable, and to a certain extent necessary, inclination on the part of any training pilot to delay taking corrective action in order to give the trainee sufficient opportunity to respond. In this particularly exacting case, with only approximately 1½ seconds available from the time the loss of thrust took effect in which to take successful recovery action, a commander's decision as to when to take over control requires fine judgement. The evidence suggests that full right rudder was indeed applied after approximately 1½ seconds, at about the last possible moment for recovery and when the aircraft was passing through the wings level attitude with a high rate of roll already established. However, to correct the situation under these conditions a considerable lateral control input was also required. The commander certainly believed that aileron control was correctly applied and indeed one would have expected such an instinctive reaction. Nevertheless the handling and performance evaluation indicates that there was no significant lateral control movement until some 2 – 3 seconds later. By this time the angle of bank had increased markedly, and the control inputs were insufficient to recover the situation in the height available. The reason for this delay can only be conjectured – possibly the gusty cross wind conditions contributed – but in these most demanding circumstances it proved critical.

No doubt appreciating the extremity of the position, and in the belief that full aileron had already been applied, the commander took the additional action of restoring power on No. 1 engine and reducing it on No. 4. However the flight recorder also shows that the No. 3 engine N_2 rpm ran down almost simultaneously with that of No. 4. In order to try to resolve this apparent conflict of evidence the No. 3 engine and its associated services underwent detailed examination but nothing was found which could account for an unscheduled engine run down, nor could any abnormality in the operation of No. 3 engine be discovered during an examination of previous flight recordings. Performance evaluation confirms that the final yaw to the right is consistent with no thrust from Nos. 3 and 4 engines. Consequently it must be concluded that a run down of No. 3 engine did occur simultaneously with the reduction of thrust of No. 4 engine. After taking into account all the available evidence, in particular the coincidence of the timing and rate of run down of the two engines, it must also be concluded that the commander inadvertently retarded the No. 3 thrust lever simultaneously with No. 4. The thrust lever positions, as seen by the other crew member, were almost certainly the result of operating cable movements and breakage as the four engines were torn off the aircraft during the ground slide. The fact remains that, lacking timely lateral control, any thrust adjustments made at this stage were unlikely to have averted a serious accident.

During the subsequent violent yaw/roll to the right the aircraft was in effect only being powered by No. 2 engine for one or two critical seconds – No. 1 engine was spooling up and had not developed any substantial power, whilst Nos. 3 and 4 engines had been retarded to idle. The result of this condition was a complete loss of climb performance so that the aircraft struck the ground whilst banked to the right.

2.4 The importance of V_{MCA} and V_{MCG}

During the investigation evidence became available which showed that in the case of an outer engine failure on the Boeing 707–436 the increase in V_{MCA} due to decreasing bank angle from the certification figure of 5^0 favourable bank, was substantially greater than had previously been believed. As can be seen from Appendix 5, the difference between the certificated value of V_{MCA} at 5^0 favourable bank angle and that at 0^0 bank is about 40 knots. In the accident case, by the time full rudder was applied, V_{MCA} had increased to about 160 knots, or some 8 knots above the aircraft's speed. However, as explained in paragraph 1.17.1, had lateral control been applied almost simultaneously, it should still have been possible to restore the situation by banking the aircraft towards the live engines so that V_{MCA} was reduced below the airspeed at the time.

It is debatable as to whether or not the course of events would have been different had the magnitude of the change of V_{MCA} with bank angle been appreciated beforehand by all those concerned. No doubt training procedures would have been critically reviewed. However at the time of the accident both the demanding nature of the aircraft during this manoeuvre and the type of corrective action required were matters which were well established and which should have been well known to all those involved. Nevertheless, in order to ensure that due emphasis be given to the subject in future, it is recommended that in the case of aircraft having an appreciable variation of V_{MCA} with bank angle between 0^0 and 5^0 of favourable bank, the relevant data should be included in their operating manuals.

In the training case, at light aircraft weights, an additional safety margin can of course be built in by artificially increasing V_R. This practice was followed by British Airtours, although in the accident situation, for the reasons already discussed, the margin proved insufficient.

A further aspect drawn into focus by this accident is the increase in V_{MCG}, affecting V_1, when the cross wind component on take-off exceeds 7 knots (see paragraph 1.17.1). This is especially relevant to training in simulated engine failures on take-off if an upwind engine is failed at or just after V_1, where V_1 is close to V_{MCG}, and all operators of similar type aircraft would be well advised to ensure that their pilots, and in particular their training staff, are aware of the implications.

2.5 Miscellaneous human factors

The crew had been on duty for 8 hours during the previous 24, including 1 hour 40 minutes of night flying, but they had had adequate rest before starting duty on the day of the accident. They all felt completely fit that morning and it is evident that the atmosphere on the flight deck was congenial, although fully professional. There is therefore no indication that the presence of fatigue or internal friction led to a lowering of operating standards.

2.6 Training accidents – general considerations

Five large four engined jet aircraft crashed during the period 1960–1976 whilst simulating an engine failure on take-off at or above V_1, the most recent case being in 1969. The decrease of this type of accident may be due in part to greater awareness of the very critical nature of the exercise and consequential tighter control on this type of training, and also no doubt to the greater use of the simulator in pre-flight training. Nevertheless it is relevant to consider whether such exercises ought to be modified in the light of this accident. There is, it is believed, an unanswerable case that the engine failure on take-off emergency needs to be included in the manoeuvres to be demonstrated for pilot competence. The question as to whether this can best be accomplished in the air or in a flight simulator is not easy to resolve. The simulator allows the full consequences of any mishandling to be demonstrated in safety. However, many simulators, particularly the older types, have a shortfall in total realism or do not provide a sufficiently accurate representation of aircraft response. Against this, the aircraft has the psychological advantage of complete realism, but only at the disadvantage of extra risk. To minimise the risk element, artificial limitations have to be placed on the exercises undertaken, which in turn detract from their value. Nevertheless there would appear to be substance for the view of some airworthiness authorities, including that of the United Kingdom, that until flight simulators are totally realistic certain key exercises should continue to be practised on the aircraft, at least on a pilot's first conversion to the type. It is therefore recommended that the situation be kept under joint review by airworthiness authorities and operators.

2.7 Survival aspects (fire)

The impact forces to which the aircraft was subjected during the accident were relatively light and probably insufficient to cause serious injury to anyone who might have been on board, even if they had been sitting in the area where the floor was ruptured.

The airport fire service arrived quickly at the crash site and brought the external fire under control with commendable speed. However, in a short time flames from the burning fuel had penetrated the cabin through the hole in the floor and spread rapidly forwards. The forward draught was almost certainly caused by the open galley door and the pilots' open side windows. Had the flight deck door been in position and closed, it would of course have largely prevented the outflow of air through the side windows. It is a matter of conjecture whether this would have materially affected the spread of the fire. As it was, the fire's intensity was sufficient to ignite the cabin furnishings, and the resultant dense smoke and toxic fumes made the task of the fire service extremely difficult. Had there been passengers on board, the reduction in visibility would almost certainly have resulted in their disorientation and could have impeded location of the emergency exits. The problem would have been compounded by the reduction in the number of usable emergency exits, due to the pools of burning kerosene outside and the unserviceable escape slide. However, in the circumstances a rapid evacuation would have been of paramount importance, because shortly after the fire entered the cabin hot fumes would have made breathing difficult and the toxic nature of the emitted gases would have dulled the occupants' will to survive.

Previous experience confirms that this type of internal fire, once established, is usually very difficult to combat. In nearly all cases the cause is similar, namely an external fire entering the cabin through an opening in the fuselage. Since external fires are usually associated with burning fuel, it follows that the maximum benefit is to be derived from preventing the fuel igniting during or immediately following an accident. Current research to reduce the spread of fire, particularly that caused by the vaporisation of fuel following its rapid release at the time of an accident, should be given a high order of priority.

The cabin furnishings with which the aircraft had been refurbished complied with the CAA specification current at the time of the issue in the United Kingdom of the aircraft's type certificate. The history of this accident and others also resulting in internal fires highlights the urgent need to produce furnishing materials which are not only more flame resistant but emit a minimum of lethal products when heated. The installation of suitable illumination or guiding signs close to the floor, where visibility is usually least restricted, would also help the evacuation of passengers from a smoke filled cabin.

Further valuable lines of investigation could be directed towards:

a) the use of high pressure water spray systems in order to dampen down the smoke and fumes in the cabin and consequently improve visibility.

b) the use of an external, forced draught system for ventilating the cabin.

c) the injection of high expansion inert foam into the cabin in order to protect the occupants from the fire and fumes whilst allowing them to breath until they can be rescued.

Certain preliminary work has already been undertaken into most of these aspects by the authorities concerned, extending over a lengthy period of time. However, the need for a further, co-ordinated and accelerated programme of research into the entire subject is underlined by the probability that in this instance, had there been passengers on board, a high percentage of casualties would have occurred despite the best efforts of the fire services.

2.8 Emergency Procedures at Prestwick Airport

The Prestwick Airport emergency orders (see paragraph 1.17.5) dealt adequately with the procedures which the various services were to follow in the event of aircraft emergencies on the airport. However, on this occasion a misunderstanding arose during the passing of the accident message from ATC to the PABX, with the result that a message with the wrong priority prefix – 'full emergency', instead of 'aircraft accident' – was circulated by the PABX. It is easy to visualise how, in the heat of the moment, this occurred; the omni-crash circuit brought into service at Prestwick since the date of the accident should lessen the chances of a recurrence. Nevertheless, it seems possible that misunderstandings of this kind could still arise in the minds of airport personnel who are not part of the ATC environment, due to the employment of the phrase 'full emergency' to cover certain categories of incidents other than aircraft accidents. This is because, from the common-sense, if non-technical, point of view, an aircraft accident is also a full emergency.

Although the phrase is used internationally, it would seem highly desirable for the authorities concerned to re-examine the possibility of substituting a less ambiguous and emotive wording.

2.9 Medical services

The medical staff were somewhat surprised when the crew suddenly arrived without any other warning, because of the misunderstanding between ATC and the PABX and the passing of the "full emergency" instead of "aircraft accident" message to the airport medical centre. The doctor and nurse who were present rendered the required assistance although the hazard of kerosene contamination did not appear to have been fully appreciated and only minimal washing facilities were available at the centre. As a result the flight engineer was wiped down but not properly washed before being sent to hospital, where plaster was applied to his still partly contaminated foot. The supervisory first officer, who was also badly contaminated and in some discomfort, did manage to wash himself. Although seen in the broad context of aircraft accidents these two crew members' sufferings were of a minor nature, for the individuals concerned the consequences were temporarily somewhat unpleasant and could have been avoided.

The British Airport Authority's reminder to airport medical authorities on the need for early treatment of people contaminated by fuel, issued shortly after the accident, and the CAA's Aeronautical Information Circular No. 111/77 on the same subject, now provide guidance on this matter. In addition to airport authorities it would be wise if airlines also ensured that their flight and other staff, who could be involved in giving aid to accident victims, were made aware of the information given in the circular.

The outside ambulance arrived at the airport with commendable speed but by the time it reached the accident site the crew had already left in another vehicle for the medical centre. These circumstances bring into question the time interval of 15 minutes allowed in CAP 168 between an ambulance being summoned and its arrival at the aerodrome. Due to the complexities of modern aerodrome layouts and the need for security systems, the time interval before the ambulance arrives at the crash site can well be extended by a further 5 to 10 minutes.

A direct consequence of the airport security system at Prestwick was the short delay caused to the ambulance when the flight engineer was taken to hospital. Although only of a minor nature in this instance, similar delays could lead to grave consequences in the event of the evacuation of serious casualties. While it is evident that the unauthorised access of vehicles onto the manoeuvring and apron areas can be dangerous it is considered that every facility should be given to ensure the speedy transit of emergency services through aerodrome security systems. It appears desirable to review CAP 168 in this respect in the light of present day conditions.

3. Conclusions

(a) Findings

(i) The documentation of the aircraft was in order and flight crew were properly licensed; the commander, a training captain, was adequately experienced to conduct the flight.

(ii) There was no pre-crash defect or malfunction of the aircraft, its flying controls or equipment. Until they were torn from the aircraft all four engines were responding correctly to thrust lever inputs.

(iii) During the take-off sequence the trainee first officer did not take action in time to correct the yaw and subsequent roll which resulted from the retardation of No. 1 thrust lever by the commander, whilst simulating an engine failure.

(iv) In a situation which required very precise judgement the commander was just too late in taking full corrective action. By the time he did so the adverse yaw and roll had increased to the extent that the aircraft was substantially below its minimum control speed for the condition. Consequently he was unable to effect recovery before No. 1 engine nacelle struck the ground.

(v) Following the impact of No. 1 engine nacelle with the ground, control of the aircraft was lost and it crashed.

(vi) The commander inadvertently retarded No. 3 thrust lever when he made power changes to engines 1 and 4 in an attempt to recover from the yaw/roll to the left. However by this time an accident was probably unavoidable.

(vii) The external fire was quickly brought under control by the airport fire service, but the cabin interior fire took 52 minutes to extinguish.

(viii) During the crew's evacuation of the burning aircraft the emergency slide did not deploy from the forward galley door due to a faulty attachment hook. As a result the crew were compelled to jump from the aircraft and they landed in a deep pool of kerosene. One was injured and all suffered from varying degrees of kerosene contamination.

(ix) The wrong type of emergency message was relayed by the PABX to the emergency services with the result that the laid down procedure for an aircraft accident was not fully implemented.

(x) The crew were not properly cleansed of kerosene contamination by the staff of the airport medical centre. Later, at a local hospital, the injured crew member had plaster applied to his kerosene contaminated broken foot.

(xi) The ambulance taking the injured crew member to hospital was slightly delayed by the requirement to comply with the airport security system.

(b) Cause

The accident was caused by a loss of control by the pilots which resulted from their delay in taking full corrective action during a simulated failure of No. 1 engine during take-off.

4. Safety Recommendations

It is recommended that:

4.1 Regulatory authorities and operators of multi-engined aircraft should review training procedures concerning engine failures at low speed, in the light of the experience gained from this accident.

4.2 In the case of aircraft having an appreciable variation of V_{MCA} with bank angle between 0° and 5° of favourable bank, the relevant data should be included in the appropriate aircraft manual.

4.3 Further research should urgently be undertaken into the prevention and control of aircraft interior fires.

4.4 The CAA, in conjunction with the other interested parties, should review the phrase 'full emergency' in its present ATC context, with a view to substituting one less likely to be confused with the report of an aircraft accident.

4.5 The responsible authorities should review the adequacy of their present arrangements for the speedy transit of emergency vehicles into and out of airports in the light of the parallel need for strong security measures.

4.6 The requirement in CAP 168 concerning the timely availability of ambulances at accidents on airports be reviewed.

4.7 Operators should draw the attention of all their personnel who may be involved in giving aid to accident victims to the information given in AIC 111/77 regarding the dangers of fuel contamination.

C C ALLEN
Inspector of Accidents

Accidents Investigation Branch
Department of Trade

September 1978

Produced in England by Her Majesty's Stationery Office, Reprographic Centre, Basildon

Bas 50752/R143 K7 9/78 TP