AIRCRAFT ACCIDENT REPORT 5/94

Air Accidents Investigation Branch

Department of Transport

Report on the accident to Cessna 550 Citation II, G-JETB at Southampton (Eastleigh) Airport on 26 May 1993

This investigation was carried out in accordance with ***The Civil Aviation (Investigation of Air Accidents) Regulations 1989***

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Department of Transport
Air Accidents Investigation Branch
Defence Research Agency
Farnborough
Hampshire GU14 6TD

9 June 1994

The Right Honourable John MacGregor
Secretary of State for Transport

Sir,

I have the honour to submit the report by Mr M M Charles, an Inspector of Air Accidents, on the circumstances of the accident to Cessna 550 Citation II, G-JETB at Southampton (Eastleigh) Airport on 26 May 1993.

I have the honour to be
Sir
Your obedient servant

K P R Smart
Chief Inspector of Air Accidents

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GLOSSARY OF ABBREVIATIONS USED IN THIS REPORT

AAIB	-	Air Accidents Investigation Branch
AIP	-	Aeronautical Information Publication
amsl	-	above mean sea level
APS	-	Aircraft Prepared for Service
ATC	-	Air Traffic Control
BCARs	-	British Civil Airworthiness Requirements
°C, M, T	-	°celsius, true, magnetic
CAP	-	Civil Aviation Publication
DME	-	distance measuring equipment
DFO	-	Duty Fire Officer
ESDU	-	Engineering Science Data Unit
FDR	-	Flight Data Recorder
g	-	normal acceleration
hrs	-	hours
IAS	-	indicated airspeed
ILS	-	Instrument landing system
JARs	-	Joint Airworthiness Requirements
km	-	kilometre(s)
kt	-	knot(s)
lb	-	pound(s)
LDA	-	Landing Distance Available
mb	-	millibar(s)
mm	-	millimetre(s)
mu	-	coefficient of sliding friction
NDB	-	non-directional beacon
nm	-	nautical mile(s)
OAT	-	outside air temperature
PAPIs	-	Precision Approach Path Indicators
PSZ	-	Public Safety Zone
PT	-	Public Transport
QFE	-	pressure setting to indicate height above aerodrome
QNH	-	pressure setting to indicate elevation above mean sea level
RESA	-	Runway End Safety Area
RFFS	-	Rescue and Fire Fighting Service
RPM	-	revolutions per minute
UK	-	United Kingdom
UTC	-	Co-ordinated Universal Time
VMC	-	Visual Meteorological Conditions
VOR	-	VHF omni range

Air Accidents Investigation Branch

Aircraft Accident Report No: 5/94 (EW/C93/5/1)

Registered Owner:	European Jet Ltd
Operator:	Aerocharter (Midlands) Ltd
Aircraft Type:	Cessna 550 Citation II
Nationality:	British
Registration:	G-JETB
Place of Accident:	Southampton (Eastleigh) Airport Latitude: 50° 56.98' N Longitude: 001° 21.32' W
Date and Time:	26 May 1993 at 0534 hrs All times in this report are UTC

Synopsis

The accident was notified to the Air Accidents Investigation Branch (AAIB) at 0550 hrs on 26 May 1993 and an investigation began the same day. The investigation was conducted by Mr M M Charles (Investigator in Charge), Mr R W Shimmons (Operations), Mr A H Robinson (Engineering) and Ms A Evans (Flight Recorders).

The accident occurred when the aircraft, with two crew members aboard, was on a positioning flight from Oxford to Southampton and overran Runway 20 after landing with a tailwind on a wet runway. After leaving the runway, the aircraft came to rest on the nearby motorway, collided with two cars, and caught fire. The two flight crew sustained minor whiplash injuries, and the three car occupants also sustained minor injuries. The aircraft was destroyed.

The investigation identified the following causal factors:

(i) The commander landed with a reported tailwind of 15 knots (kt) which was outside the aircraft maximum tailwind limit of 10 kt specified in the Cessna 550 Flight Manual.

(ii) The co-pilot did not warn the commander that he was landing with a reported tailwind component which was outside the aircraft limit.

(iii) With a tailwind component of 10 kt, the landing distance available was less than the landing distance required.

Three safety recommendations were made during the course of the investigation.

1 Factual Information

1.1 History of Flight

The crew of G-JETB reported for duty at Oxford between 0430 and 0505 hrs on 26 May 1993. Their roster for the day was to position the aircraft to Southampton, pick up eight passengers and fly them to Eindhoven, take split-duty rest, fly eight passengers to Southampton and finally fly G-JETB to Biggin Hill for some engineering maintenance. G-JETB had arrived at Oxford the previous evening and had then been refuelled to full tanks. The charter movement between Southampton and Eindhoven was a regular occurrence each Wednesday; the normal arrangement had been for the aircraft and crew to position at Southampton the previous evening but, over the last few weeks the practice was for the operating crew to position the aircraft early on the Wednesday morning. The co-pilot had agreed with the airport authorities at both Oxford and Southampton that the aircraft would operate outside normal hours on the understanding that no fire cover would be provided. On the evening of 25 May 1993 he had telephoned Southampton operations to submit a flight plan for the flight to Eindhoven and also to confirm the early arrival at Southampton the next morning. Throughout the flight from Oxford to Southampton, the commander handled the aircraft from the left seat and the co-pilot operated the radio.

Following the takeoff from Oxford at 0519 hrs the crew contacted Brize Norton ATC and agreed a Flight Information Service. They maintained VMC for the transit at 2,400 feet QNH and called Southampton ATC on their alternate radio at 0525 hrs when they were approximately 30 nautical miles (nm) from Southampton. The Southampton controller was surprised at their initial call and advised them that the airport did not open until 0600 hrs. The crew informed him that arrangements had been made for an early arrival and the controller asked them to standby while he checked this agreement. At 0527 hrs he called G-JETB, informed the crew that they could land before the normal opening hours and asked them to confirm that no fire cover was required. The crew confirmed this and were then told that Runway 02 was in use with a wind of 020°/14 kt and that there was a thunderstorm right over the airport. The crew then advised Brize Norton radar that they were going to Southampton ATC and left the Brize Norton frequency. Following a further check with Southampton they were given the 0520 hrs weather observation: "SURFACE WIND 040°/12 KT, THUNDERSTORMS, 2 OKTAS OF STRATUS AT 800 FEET, 3 OKTAS OF CUMULONIMBUS AT 1,800 FEET, TEMPERATURE 12°C, QNH 1007 MB, QFE 1006 MB, THE RUNWAY IS VERY WET."

At 0530 hrs the controller asked the crew for the aircraft type and, after being told that it was a Citation II, told the crew that the visibility was deteriorating ("NOW 2,000 METRES IN HEAVY THUNDERSTORMS") and cleared them to the

Southampton VOR at 3,000 feet QNH. After checking that they were now IFR the controller confirmed the clearance, and the QNH of 1007 mb, and informed the crew that there was no controlled airspace and that he had no radar available to assist them. Shortly afterwards the controller advised the crew that: "ENTIRELY AT YOUR DISCRETION YOU MAY ESTABLISH ON THE ILS LOCALISER FOR RUNWAY 20 FOR VISUAL BREAK-OFF TO LAND ON RUNWAY 02." The commander accepted this offer and, within the cockpit, asked the co-pilot for the surface wind. He was informed that it was 040° but that earlier they had been given 020°/14 kt. At 0532 hrs the commander had positioned on the ILS for Runway 20 and began his descent; the co-pilot advised Southampton that they were established. The controller acknowledged this and again passed the QNH. Shortly afterwards he asked the crew to report at the outer marker and this message was acknowledged. At 0533 hrs the crew called that they were visual with the runway and the controller cleared them for a visual approach, left or right at their convenience, for Runway 02. As this transmission was taking place, the commander informed his co-pilot that they would land on Runway 20. The commander decided this because he could see that the weather at the other end of the runway appeared very black and he had mentally computed the tailwind component to be about 10 kt. After a confirmation request from the co-pilot to the commander, the co-pilot informed the Southampton controller that they would land on Runway 20. The controller then advised them that: "YOU'LL BE LANDING WITH A FIFTEEN KNOT, ONE FIVE KNOT, TAILWIND COMPONENT ON A VERY WET RUNWAY"; this was immediately acknowledged by the co-pilot with: "ROGER, COPIED THANK YOU".

The crew continued with their approach, initially at 15 kt above their computed threshold speed (V_{REF}) of 110 kt and then at a constant V_{REF}+10 kt. Within the cockpit the commander briefed the co-pilot that if they were too fast the co-pilot was to select flap to the take-off position and they would go-around; they also discussed the use of the speedbrake and the commander stated that he would call for it when he wanted it. The speed at touchdown was within 5 kt of the target threshold speed and touchdown was in the vicinity of the Precision Approach Path Indicators (PAPIs), according to witnesses in the Control Tower and on the airport; the commander was certain that he had made a touchdown within the first 300 feet of the runway. The PAPIs are located 267 metres along the runway. Speedbrake was selected as the aircraft touched down and, although the commander applied and maintained heavy foot pressure on the brakes, no retardation was apparent; external observers reported heavy spray from around the aircraft. At some stage down the runway the commander stated that the brakes were not stopping them and the co-pilot called for a go-around; the commander replied: "NO WE CAN'T" as he considered that a go-around at that stage would be more dangerous. He maintained brake pressure and, in an attempt to increase distance, steered the aircraft to the right edge of the runway before trying to steer back left. Initially the aircraft nose turned to the left and the aircraft slid diagonally off the right side of the runway on to the grass. It continued across the grass for a distance of approximately 233 metres while at the same time yawing to the left. However, 90 metres beyond the end of the runway there is an embankment which forms the side of the M27 motorway and G-JETB slid down this embankment on to the motorway. The aircraft continued to rotate as it descended and came to rest, having turned through approximately 150°, with its tail on the central barrier (see Appendix A). During these final manoeuvres the aircraft collided with two cars travelling on the eastbound carriageway; the aircraft and one of the cars caught fire.

During the approach of the aircraft, the airport Rescue and Fire Fighting Service (RFFS) duty officer had discussed with the duty ATC controller the imminent arrival of G-JETB. Although not all checks had been complete, the fire officer offered his two fire vehicles as a weather standby; he did not declare his section operational but agreed with ATC that they would position themselves to the west of the runway. When the aircraft was 1/2 to 2/3 down the runway, the ATC controller considered that the aircraft would not stop in the runway available and activated the crash alarm. The fire section obtained clearance to enter the runway after G-JETB had passed their position and followed the aircraft. Assessing the situation on the move, the fire officer ordered the FIRE 2 vehicle to disperse through the crash gate to the motorway, and took his own vehicle (FIRE 1) to the edge of the embankment. On arrival, the fire section contained the fires. The occupants of the aircraft and cars escaped with minor injuries.

1.2 Injuries to persons

Injuries	Crew	Passengers	Others
Fatal	-	-	-
Serious	-	-	-
Minor / None	2	-	3

1.3 Damage to aircraft

Aircraft destroyed.

1.4 Other damage

A Ford Sierra and a Renault 18 GTS, travelling eastbound on the M27 motorway, were struck by the aircraft. The Ford came to rest on its roof and the Renault engine compartment caught fire. Additionally, both vehicles had sustained heavy impacts.

1.5 Personnel information

1.5.1	Commander:	Male, aged 63 years	
	Licence:	Airline Transport Pilot's Licence	
	Instrument rating:	Renewed on 1 May 1992	
	Base check:	6 March 1993	
	Line check:	10 March 1993	
	Medical:	Class 1 valid until 1 December 1993	
	Flying experience:	Total all types	16,700 hours
		Total on type	850 hours
		Last 90 days	71 hours
		Last 28 days	44 hours
	Duty time:	32 hours rest prior to commencing duty at 0500 hrs on 26 May 1993.	
1.5.2	First officer:	Male, aged 43 years	
	Licence:	Commercial Pilot's Licence	
	Instrument Rating:	Renewed 21 December 1992	
	Base check:	21 December 1992	
	Line check:	21 December 1992	
	Medical:	Class 1 valid until 30 June 1993	
	Flying experience:	Total all types	1,322 hours
		Total on type	109 hours
		Last 90 days	77 hours
		Last 28 days	33 hours
	Duty time:	12 hours rest prior to commencing duty at 0430 hrs on 26 May 1993.	

1.6 Aircraft information

1.6.1 Leading particulars

Type:	Cessna 550 Citation II
Constructor's number:	550-0288
Year of manufacture:	1981
Certificate of Registration:	Registered to European Jet Ltd

Certificate of Airworthiness:	Transport Category (Passenger), last renewed on 21 June 1992, valid until 20 June 1993
Certificate of Maintenance Review:	Dated 19 March 1993, valid to 20 June 1993

By the evening preceding the accident, the aircraft had achieved 4,315.2 hours and 3,306 landings. There were no defects recorded in the technical log. The next maintenance check, a Phase 10, was due at 4,308 aircraft hours or on 20 June, whichever occurred first. However a concession had been applied for on 24 May, extending the check interval of 100 hours by 10%, thereby making it due at 4,318 hours. The aircraft had been scheduled for a flight to Biggin Hill, for maintenance, on the evening of the day the accident occurred.

1.6.2 Aircraft weight and centre of gravity

The maximum certified take-off weight of G-JETB detailed in the Citation Flight Manual and the Aerocharter (Midlands) Operations Manual is 13,300 lb; the maximum certificated landing weight is 12,700 lb.

G-JETB was last weighed at IDS Citation Centre, Hurn on 25 September 1991. At that time the aircraft had an Aircraft Prepared For Service (APS) weight of 8,251 lb.

On departure from Oxford on 26 May 1993 the aircraft was full of fuel which resulted in a fuel weight of 5,000 lb; therefore the ramp weight at Oxford was 13,251 lb. The aircraft was below the maximum certified take-off weight.

Based on fuel flow figures from the Citation Flight Manual and with an allowance for taxi and takeoff, the fuel used up to the time of landing at Southampton was calculated as 723 lb. This would result in a landing weight of 12,528 lb; this accords with the crew's assessed landing weight of 12,500 lb. Therefore the landing weight of the aircraft was within its maximum certified landing limit, subject to performance considerations.

The aircraft was correctly loaded within its centre of gravity limits.

1.6.3 Limiting wind conditions

The maximum tailwind component for the aircraft for landing is 10 kt; this limitation is included in both the Citation Flight Manual and the Aerocharter (Midlands) Operations Manual.

1.6.4 Description of braking system

The aircraft is equipped with a power brake and anti-skid system operating on disc packs fitted to the main landing gear wheels. The power is provided by a hydraulic pump driven by a DC electric motor, with the pump charging an accumulator. The system is designed such that the motor is energised in order to maintain the accumulator pressure within a specified band. A caption on the central warning panel illuminates in the event of low system pressure. The brakes are actuated from a master cylinder connected to each rudder pedal.

The essential components of the anti-skid system are the wheel transducers, an electro-hydraulic servo valve and an electronic control box. The transducers are housed within the axles and consist of small electrical generators, each sending a signal with a strength proportional to the wheel RPM, to the control box. This in turn sends signals to the servo valve such that if one or both wheels start to skid, thereby resulting in a rapidly reducing RPM signal, then the servo valve acts to reduce pressure to the brakes, thus preventing the wheel from skidding.

1.6.5 Scheduled landing performance

The Landing Distance Available (LDA) from the UK AIP for Runway 20 at Southampton is 1,605 metres. Figures supplied by the Cessna Aircraft Company, for the Citation II on the UK Register gave a total scheduled landing distance of 5,598 feet (1,706 metres). This was for an aircraft landing at a weight of 12,500 lb with a 10 kt tailwind, using a V_{REF} of 108 kt IAS, and a touchdown speed of 104 kt IAS, on a runway at sea level with zero slope and an OAT of 12°C. This predicted landing distance comprised an airborne distance of 1,867 feet (569 metres) and a ground roll distance of 3,731 feet (1,137 metres). Similarly for a 15 kt tailwind, with other input conditions the same, the total landing distance was estimated by Cessna to be 6,667 feet (2,032 metres) with an airborne distance of 2,024 feet (617 metres) and a ground roll distance of 4,643 feet (1,415 metres).

These figures are the dry runway landing distance multiplied by 1.92 to comply with British Civil Airworthiness Requirements (BCARs). These use a technique to measure landing performance on a dry runway that assumes a normal threshold speed, and the application of a 1.92 factor to allow for the operational conditions and a wet runway. No attempt is made to measure performance on a wet runway. The unfactored ground roll distances assume an effective coefficient of friction (mu) of 0.5 reducing linearly from 106 kt to a mu of 0.36 at 120 kt. The Flight Manual quotes the landing distance as 5,554 feet (1,692 metres), but does not give a landing distance figure for the 15 kt tailwind case as this is outside Flight

Manual limitations. [Note, this figure is 44 feet (14 metres) less than the figure quoted by Cessna in the previous paragraph].

The Flight Manual also quotes a low braking friction landing distance, this assumes a mu of 0.05. In this case for a 10 kt tailwind the total landing distance, under the same conditions as above was predicted to be 15,760 feet (4,803 metres), including a factor of 1.3. This figure was not divided into airborne and ground distances; however from the normal landing figure for airborne distance and removing the factor, a ground distance for low braking friction was estimated as around 3,400 metres.

The results of runway friction measurements made at Southampton are presented at paragraph 1.10.4.

From figures supplied by Cessna, the maximum kinetic energy which can be absorbed by the brakes at a landing weight of 12,500 lb is 6.995×10^6 ft lb, which corresponds to a maximum brake application groundspeed of 112 kt.

1.6.6 Distance required to go-around

The distance required to accelerate from V_R (103 kt IAS) on the runway to V_2 (111 kt IAS) at 35 feet above the runway, with a 15 kt tailwind was calculated by Cessna to be 1,600 feet (488 metres). If the aircraft had decelerated to below V_R the distance required would be greater to allow for acceleration to V_R.

The first call by the co-pilot to go-around was heard on the Cockpit Voice Recorder (CVR) four seconds before the aircraft left the side of the runway which would have been approximately 290 metres before the end of the runway. The distance remaining when the co-pilot called for a go-around was therefore less than that required to achieve the go-around manoeuvre with the aircraft at a speed of V_R or less.

1.7 Meteorological information

1.7.1 Synoptic situation

There was an area of low pressure slow moving to the south west of the British Isles with an area of thunderstorms moving slowly north and north west across Hampshire. Visibility was 6 km at best, falling to 2,000 metres in the heavier rain. Cloud was scattered stratus base between 800 and 1,000 feet, broken cumulus base 2,000 to 3,000 feet, occasional cumulonimbus base 1,500 feet with overcast altocumulus 9,000 feet above. The surface wind was 030°/10 to 15 kt. Surface temperature was +11°C and the mean sea level pressure was 1007 mb.

1.7.2 Actual observation

Observations made by the duty air traffic controller at Southampton (Eastleigh) Airport on 26 May 1993 indicated the following:

a. 0520 hrs: Surface wind 040°/12 kt, visibility 9,000 metres, thunderstorms, 2 oktas of stratus at 800 feet, 3 oktas of cumulonimbus at 1,800 feet, temperature +12°C and sea level pressure setting (aerodrome QNH) was 1007 mb.

b. 0550 hrs: Surface wind 020°/18 kt, visibility 2,000 metres, thunderstorms, 2 oktas of stratus at 800 feet, 3 oktas of cumulonimbus at 1,800 feet, temperature 11°C and QNH 1007 mb.

Note: In 1986 the duty air traffic controller at Southampton had successfully completed an approved training course for air traffic control staff in the making and reporting of weather observations. The course was carried out at the Meteorological Office at Bracknell.

1.7.3 Aftercast

An aftercast provided from the Meteorological Office at Bracknell confirmed the reports of thunderstorms at 0520 hrs and 0540 hrs and concluded that it was highly likely that standing water on the runway would have been in evidence. It was also considered most likely that severe turbulence and down draughts would be present. At Otterbourne, 6 km north of Eastleigh, $^1/_3$ inch of rainfall was recorded between 0400 hrs and 0600 hrs.

1.7.4 Anemometry

The anemometer is located on top of the glideslope aerial. This 40 foot high aerial is situated off the western side of the runway abeam the PAPIs for Runway 20. The display is directly in front of the local air traffic controller; it comprises a digital display showing the magnetic wind direction and the strength in knots, encircled by an analogue display of wind direction. Additionally, there are two wind socks located to the east of the runway, one near each end.

1.8 Aids to navigation

Runway 20 at Southampton has an instrument landing system (ILS) producing a 3° glideslope, with outer and middle marker radio beacons. A non-directional beacon (NDB) is situated close to the threshold. Additionally the crew had range information available from the Southampton VOR/DME.

The ILS was flight checked on 10 March 1993. The monthly maintenance was carried out on 24 May 1993; the integrity of the ILS was checked on

25 May 1993 and the remote indicators showed a seviceable system on the morning of 26 May 1993.

1.9 Communications

VHF and UHF communications were satisfactory. Tape recordings were available of transmissions on the Southampton ground-to-air frequencies, ground-to-ground frequencies and console telephones.

1.10 Aerodrome and approved facilities

1.10.1 Runway physical characteristics

Runway 20 is 1,723 metres in length and 37 metres wide. There is a displaced threshold of 45 metres and the declared LDA is 1,605 metres. The runway is provided with both the internationally required strip end of length 60 metres, and the recommended minimum length Runway End Safety Area (RESA) of 90 metres as set out in 'Civil Aviation Publication (CAP) 168 Licensing of Aerodromes'. The surface of the runway is brushed concrete and surface water drainage is provided along the eastern side.

1.10.2 Runway lighting

The approach lights comprise 360 metres of high intensity centreline lights with one cross-bar. The threshold was designated by green high intensity threshold lights with green wing bars. The runway lighting consisted of high intensity omni-directional white edge lights and red runway end lights. Runway centreline lights were not installed. PAPIs, calibrated for a 3° visual glideslope, were installed for approaches to Runway 20; these are located 267 metres from the threshold and checked weekly for accuracy. All the approach and runway lights were illuminated at the time of the accident.

1.10.3 Runway slope

Runway 20 slopes down from the landing threshold at 43 feet amsl to 30 feet amsl at the threshold of Runway 02.

1.10.4 Runway friction measurements

Following the accident the AAIB requested that a runway friction calibration be carried out by the Aircraft Ground Operations Group of the Cranfield Institute of Technology. A previous calibration had been conducted in 1990 as part of a CAA trial to investigate the periodicity required for runway friction measurements. The first calibration at Southampton took place in 1982. All three calibrations used the same mu-meter machines fitted with a self-wetting attachment capable of depositing a measured amount of water beneath the measuring wheels. The flow rate was adjusted to produce a water film thickness of approximately 0.5 mm. The friction measuring range of the mu-meter is from 0 to 1. The calibration of the machine ensures that the readings on a dry runway surface are in the region of 0.8 and consequently readings on a wet surface should be lower than this figure.

In addition to two dry calibration runs, (one at the beginning and end of the test period) a number of runs were carried out at various speeds along the full length of the runway on either side of the centreline. The towing vehicle was a 3 litre Ford Capri equipped with a water tank and pump to supply the self-wetting system on the mu-meter.

The results of the calibration are summarised at Appendix B. The average wet friction reading adjacent to the runway centreline was 0.57. The comparative values from the 1982 and 1990 calibrations were 0.55 and 0.60 respectively. The slight decrease since the 1990 reading was considered to be well within the range which can be caused by seasonal variation and machine tolerances. The results also showed that there was no significant decrease in friction levels with increasing speeds. Note that areas of low friction caused by standing water will not be identified by these tests.

Rubber deposits in the touchdown areas were subjectively assessed as light. The friction readings here reduced to 0.5, but the areas involved were small and were not considered to have caused significant problems.

The ICAO Annex 14 recommendations concerning friction coefficients, as measured under mu-meter Method 2 conditions, are as follows:

Design objective for new runway surface	**Maintenance planning level**	**Test water depth (mm)**	**Test speed (kph)**
0.65	0.45	0.5	130

The airport authorities perform periodic monitoring of the surface friction characteristics, in accordance with the requirements of CAP 168 using a GripTester GT045 machine. This is towed at speeds of around 40 mph and operates on the 'dragging tyre' principle whereby the measuring wheel is geared such that it rotates at a slightly reduced RPM compared to the freely rolling main wheels. The friction value decreases with increase in speed and the self-wetting equipment used on the mu-meter calibration tests produces only the equivalent of a damp surface. Thus the results obtained by the two methods are not directly comparable. However it is estimated that a mu-meter reading of 0.39 (the low friction notification value) equates to a GripTester reading of 0.5 at 40 mph.

GripTester readings taken in drying conditions after the accident produced an average value of 0.65. Between the time of the accident and the time this measurement was taken, 54 minutes later, there had been no further rain, allowing the runway to drain and dry. Therefore it can be assumed that the mu at the time of the accident was less than 0.65. Subsequent measurement of wet runway conditions produced typical mu values of 0.4.

The Engineering Sciences Data Unit (ESDU) has for many years issued Data Sheets and Memoranda providing evaluated data and authoritative information for use in engineering design. The aeronautical aspects of this work are sponsored by the Royal Aeronautical Society. ESDU Item Number 71026 covers 'Frictional and retarding forces on aircraft tyres'.

Appendix C, Figure 1 summarises the mu-meter and GripTester measurements together with an expected wet runway maximum mu, as obtained from ESDU Item Number 71026. This is valid for a ribbed aircraft tyre on a brushed concrete surface, with a braking system which is not torque limited. Also shown is an estimated effective wheel braking coefficient for an adaptive anti-skid system which was derived using factors given in the same ESDU item, for a normally wet runway.

The Cranfield tests gave a measure of the maximum achievable mu for the runway; these values were higher than those predicted from the ESDU item, but were within the tolerance band quoted. There was wider variation in the two values measured by the GripTester, post-accident and on a wet runway.

1.11 Flight recorders

A Flight Data Recorder (FDR) was not required for this flight and none was fitted. Investigation of the performance aspects of this accident was considerably hampered by the lack of flight recorder evidence, in particular aircraft speed during the landing.

The CVR was a Fairchild A100A. A good replay was obtained for the whole of the flight from Oxford. The track allocations were as follows:

Channel 1	Co-pilot
Channel 2	Area Microphone
Channel 3	Spare
Channel 4	Commander

The approach speed was stated as 110 kt on the CVR, and there were four calls from the co-pilot during final approach of "PLUS TEN", indicating an airspeed of 120 kt. Although it was not possible to identify exactly where touchdown occurred from the CVR, there was a call from the commander of "SPEEDBRAKE", 39.5 seconds before the tape ended. Sixteen seconds before the end of the recording the commander stated: "BRAKES AREN'T STOPPING US", and 2.5 seconds later the co-pilot called for a go-around to which the commander responded: "NO WE CAN'T". This later call was made four seconds before the aircraft left the side of the runway. There was a second call to go-around from the co-pilot one second before the aircraft left the side of the runway. The recording ended 9.5 seconds after the aircraft left the side of the runway as the aircraft traversed the bank down to the motorway.

The CVR is stopped by the operation of an inertia switch fitted in the cabin roof. Subsequent engineering examination showed that this switch had operated during the crash.

There were some periodic 'thump thump' noises on the CVR. These occurred every 1.5 seconds during the landing run until just before the aircraft left the side of the runway. It was not possible to identify the source of the noise; the runway block construction at Southampton was not at an interval which would produce this periodicity, and there was no centreline lighting. Operation of the braking system was also investigated and nothing was found to explain this noise. The cycling of the anti-skid system under light or heavy braking, in low friction conditions, is between two and seven times in a 1.5 second period.

1.12 Wreckage and impact information

1.12.1 Accident site examination

The initial touchdown point could not be identified within the tyre marks left by other aircraft in the touchdown zone of Runway 20. The first discernible marks attributed to G-JETB were nose and right mainwheel tyre marks on the right side of the runway shortly after the intersection of the southern taxiway, approximately 1,380 metres from the threshold. The marks took the form of pale coloured tracks in the concrete where the surface appeared to have been cleaned by the passage of the tyres. The lateral displacement between the marks indicated that the aircraft was yawed approximately 17° to the right at this point. From here the aircraft started to run straight, with the left mainwheel tyre mark becoming visible. The aircraft departed the right-hand edge of the runway approximately 155 metres beyond the southern taxiway intersection. This departure point was 1,531 metres from the threshold and 1,264 metres from the estimated touchdown point.

The wheel marks on the grass indicated that the aircraft ran straight for approximately 50 metres before yawing to the left, with the nosewheel mark eventually merging with the left mainwheel mark. The geometry of the landing gear is such that the yaw angle would have been about 22° at this stage. A few metres further on, additional marks appeared outboard of the left mainwheel track; these were thought to have been made by the underside of the forward fuselage and the nose gear leg after failure of the nosewheel attachment. Shortly afterwards, a small excavation in the right mainwheel track suggested the collapse of the right main gear. The tracks indicated that the aircraft reached a maximum lateral distance of 30 metres from the edge of the runway before turning back to the left. Approximately 40 metres beyond the end of the runway paving, the aircraft, following a track of 191°M, slipped down a steep embankment, some 3 metres high, and came to rest across the eastbound carriageway of the M27 motorway. The aircraft had continued to yaw to the left during the final part of the groundslide and came to a halt on a heading of 050°M.

The passage of the aircraft across the road had left a number of abrasions on the concrete surface. The light nature of these marks suggested that the impact with the road had not been particularly violent.

The aircraft collided with two cars, a Ford Sierra and a Renault 18 GTS, as it crossed the carriageway. These were examined by accident investigators from the Hampshire Constabulary, who found smeared aluminium deposits on the undersides. These, taken in conjunction with scratches later found on the aircraft's right wing upper surface, suggested that the vehicles had been picked up bodily by the wing of the aircraft. In addition, there was evidence of lighter contact between the right engine nacelle and the rear nearside wings of the cars. The Sierra had been rotated through 180° and rolled onto its left side during its impact with the aircraft. It had then slid along the central reservation in its original direction of travel, with its roof in contact with the barrier, before moving back out onto the right-hand lane and coming to rest on its roof.

The Renault, which had probably been travelling behind the Sierra, had sustained a severe frontal impact. This appeared to have been the consequence of striking the road in a nose-down attitude following its collision with the wing of the aircraft. The car's front suspension had been damaged and some components from this area were found close to the aircraft.

1.12.2 Examination of the aircraft

The aircraft came to rest on its belly, with the right main gear and the nosewheel detached, and the left main gear collapsed in the outboard direction, but otherwise substantially intact. The tailcone and underside of the rear fuselage had been damaged as a result of contacting the barrier on the central reservation of the motorway. The left wing was propped up by the collapsed main landing gear, such that the left tip was raised in excess of one metre above the ground. The outboard sections of both wings had distorted upwards as a result of ground contact. This damage to the wings had extended to rupturing the wing tank cavities, thereby allowing fuel to pool around the underside of the aircraft. No fuel remained in the right wing, which was extensively burnt. Fuel was observed to be leaking from the inboard end of the left wing for several hours after the accident. During the recovery operation in excess of 45 gallons of fuel were handpumped from the left wing tank.

1.12.3 Subsequent detailed examination of the aircraft

1.12.3.1 Cockpit readings and selections

The relevant readings and selections were as follows:

Landing gear	Down
Flaps	Mid position (ie Take-off/Approach)
Flap indicator	Mid position
Pitch trim	Mid (Take-off/Go around) position
Left throttle	Fuel cut-off
Right throttle	Idle power
Anti-skid	On
Landing lights	Off
Recognition lights	On
Anti collision beacon	On
Master switch	Off

Most of the circuit breakers on the left-hand panel had tripped, although it was likely that this was mainly the result of the external fire affecting the rear of the panel before the battery was disconnected. The only circuit breakers that had not tripped were: STDBY GYRO, RH FIRE DETECT and LH BUS NO 1, the last being a 75 amp breaker.

A total of 17 circuit breakers had tripped on the right-hand panel, which had sustained little visible fire damage other than being smoke blackened.

1.12.3.2 Flying controls

The primary flying controls were not relevant to the circumstances of this accident and hence were subjected only to a superficial examination.

The speedbrakes appeared to be in the fully deployed position on the left wing, whilst those on the right were damaged in a way that could not have occurred had they been retracted. The right wing upper spoiler, together with some of the operating linkage, was found in the Ford Sierra, although it was not clear whether this occurred during the accident or had been placed there by someone in the immediate aftermath. The speedbrake selector on this aircraft is a toggle switch on the pedestal, spring biased to the neutral position and guarded to minimise the risk of inadvertent operation. The spring biasing meant that there was no way of confirming the selection by means of the switch position.

The flaps appeared to be other than in the retracted position and, as noted in paragraph 1.12.3.1, the flap pre-select lever, was found in the mid position. There are three detented positions; up, mid (Take-off/Approach) and land (fully down). Movement of the flap lever out of a detent is effected by first pushing downwards and then moving the lever to the desired position. This completes either the up-flap or down-flap circuit by actuating the 'UP' or 'DOWN' position switches located within the pedestal. This in turn signals the two DC flap operating motors (one operating as a back-up in the event of the other failing) in the rear fuselage under the cabin floor. The motors operate the flap actuation cables via a reduction gearbox, drive shafts, and sprocket and chain assemblies. The flap position indicator system is driven from the drive shafts, and this moves a pointer in a slot adjacent to the flap lever. It is the rotation of the pointer that deactuates the position switch when the flaps have travelled to the pre-selected position.

The fact that the indicator pointer was in agreement with the selected position was considered to be a reasonable indication that the aircraft struck the road with the flaps at the 'as found' setting, ie Take-off/Approach. The fuselage had remained structurally intact, thereby maintaining the rigging and the cable tension in the indicator system. Had the selector been inadvertently knocked away from the fully down position, either during the groundslide or the evacuation, then it is unlikely that the flaps would have been able to move very far due to the mechanical damage to the mountings and linkages. This would have resulted in a mismatch between the selected and indicated positions, and could have stalled the flap motors thereby tripping the circuit breaker. In fact the flap motor and flap control circuit breakers, located on the left-hand panel in the cockpit, had both tripped, although, as noted in Section 1.12.3.1, it is probable that this was as a result of the fire.

The scope for accidental movement of the flap selector appeared to be limited due to the pushing down action required to move it out of a detented position. However, it was noted that the fully down detent was not as positive as for the take-off position.

Both crew members were adamant that the flaps were fully down for landing; this was supported by a trial flight which indicated that the speed could not have been reduced to that stated on the CVR without the additional drag provided by full flap.

1.12.3.3 Tyres

The tyres were examined with a view to establishing the effect of their condition on the braking performance of the aircraft.

The aircraft records showed that all three tyres had been replaced on 7 September 1992 at 4,016 aircraft hours and 2,991 landings, due to the existing tyres being 'worn to limits'. On 16 April 1993, the right-hand main tyre was replaced with the hours and landings being respectively 4,233 and 3,206. The relevant worksheets noted that the tyre sidewall had been damaged, as had the brake heatshield, which was replaced at the same time. How this damage occurred was not recorded, although the implication is that it was the result of a hard landing, causing tyre deflection severe enough to bring the sidewall in contact with the heatshield.

Photographs of the mainwheel tyres are presented at Appendix D. The right tyre had escaped the worst effects of the fire due to the right leg becoming detached. The examination, which was conducted in the presence of a representative of the tyre manufacturer, showed that this tyre had been in good condition, with no evidence of it having been run in an under-inflated condition. As is typical with this type of aircraft, the tyre had worn slightly more on the inboard side, such that the depth of the tread grooves varied from approximately 5 mm to 8 mm across the tyre width.

The left tyre had suffered considerable fire damage, although it was apparent that it had been in a more advanced state of wear than the right. It was noted on one of the few unburnt sections that the radial grooves on the sidewall of this tyre were shorter than those on the right, due to the tread wearing down to beyond the ends of the grooves. This observation resulted in an estimate of the tread groove depth remaining being no more than 1 to 2 mm at the time of the accident.

Finally, none of the tyres showed any evidence of reverted rubber that is often associated with hydroplaning; however this does not necessarily mean that hydroplaning did not occur.

1.12.3.4 Electrical system

Whilst the electrical system was not pertinent to the causes of the accident, the post-accident fire may have been electrically initiated and/or sustained. Video recordings taken by the fire service and the nearby Ford Motor Company security cameras indicated that the anti-collision beacon on top of the rudder remained operating in excess of 20 minutes after the accident. An engineer from the airport turned off the battery master switch (operating it from outside the aircraft via the direct-vision (DV) window), yet the anti-collision light was only extinguished when the battery, located in the rear fuselage, was physically disconnected.

DC electrical power from the engine-mounted generators is fed into a junction box located aft of the pressure bulkhead in the tailcone of the aircraft. A number of circuit breakers are located on the sides of the box, and 80 amp current limiters (heavy duty fuses) protect the three cables that run along each side of the fuselage from the main busbars to the extension busbars feeding the distribution panels on each side of the cockpit. The battery feeds the same buses via a contactor connected to the hot battery busbar, and which is operated by the battery master switch. When the latter is selected 'ON', an electrical path to earth is made which energises the contactor.

The interior of the rear fuselage in which the junction box is located had remained largely unaffected by the fire. None of the current limiters had failed, although many of the circuit breakers had tripped. However the anti-collision beacon circuit breaker had not tripped. It therefore appeared that the master switch had become ineffective, the most probable explanation being that the fire affected the cable looms on the left side of the cockpit, such that the battery contactor remained earthed and hence energised, thereby maintaining battery power on the busbars. This was confirmed when a resistance check was made between one of the contactor terminals and the aircraft structure; this was measured as 300 ohms, where an open circuit condition would normally exist.

The landing lights, which are attached to the main landing gear legs, are each supplied via a 15 amp circuit breaker, which were found not to have tripped. The circuit becomes 'live' when the landing gear is locked down, with the bulbs illuminating when the landing light switch is selected 'ON', thereby opening a path to earth.

The aircraft was equipped with two inertia switches, one associated with the CVR, the other energising the emergency lighting system. These are identical 5g switches located in the cockpit roof adjacent to the CVR area microphone. In the event of a deceleration in excess of 5g in the longitudinal direction, the CVR is stopped and the emergency lights are switched on. Electrical and visual examination, confirmed that the switches had operated. In fact the switches were mounted at an angle of 15° to the horizontal, such that they could also be activated by a vertical acceleration. The aircraft's impact with the motorway barrier imparted a forward acceleration relative to the aircraft axis and thus would not be expected to activate the inertia switches. It is therefore likely that this occurred either when the nose gear collapsed or when the aircraft struck the motorway after sliding down the embankment.

1.12.3.5 Doors

The crew were forced to evacuate via the emergency exit on the right-hand side of the aircraft due to the difficulty they encountered in attempting to operate the handle on the main door. However, during the wreckage recovery operation, which necessitated lifting the fuselage onto a trailer, the door was reportedly opened without undue difficulty.

Subsequent examination revealed that the latch mechanism within the door was intact, although it was somewhat stiff in operation due to the effects of the fire. The final one third of the movement on the internal handle retracts the lockpins into the door, thereby disengaging them from the sockets in the door frame and allowing the door to be opened. This operation of the lockpins was checked with the door open; the door could not subsequently be closed and latched. During attempts to do so, it was noted that the lockpins were not aligning with the sockets due to distortion in the door frame and/or door. In particular, gaps were observed between the lower rear edge of the door and the frame. It is thus probable that the crew's difficulty with the door stemmed from fuselage distortion that might reasonably have been expected to occur during the accident. This would have imposed shear loads on the lockpins that may have required a significant force to overcome. The apparent ease with which the door was subsequently opened could have resulted from a 'stress relieving' process occurring as a consequence of the fire.

1.12.3.6 Engine controls

No problems were reported with the engines; hence it was not necessary to examine them in detail. The left engine cowling had suffered some heat damage to the underside, but the engine itself bore no evidence of being affected by the fire. The right engine, which had continued to run after the aircraft had come to rest, had sustained considerable external fire damage, as had the nacelle. The engine reportedly stopped when the fire services directed foam into the intake.

In the cockpit, the left throttle was found in the fuel cut-off detent at the aft limit of the gate. The right throttle was approximately in the idle position immediately ahead of the detent. The throttle levers have spring loaded triggers which have to be raised in order to allow lever movement below the idle position and into the fuel cut-off detent. Throttle movement is transmitted to the engines via 'teleflex' type cables. These run in the keel of the aircraft and had probably been affected by the fire, as the throttle levers could only be moved with great difficulty. The throttle quadrants on the fuel control units, which are located on the left side of each engine, indicated the same throttle settings as the cockpit levers.

1.13 Medical and pathological information

Not applicable.

1.14 Fire

1.14.1 General

Both pilots report that there were signs of small fires under the fuselage and wings when they vacated the aircraft. The co-pilot also refers to a ring of flame outside the aircraft while he was trying unsuccessfully to open the normal exit. After the pilots vacated the aircraft, the commander realised that he had not closed down the engines and went back inside the cockpit to shut them down. Subsequent examination of the engine controls indicate that the left engine had been closed down but that the right engine was still at the idle setting. Both the air traffic controller and the RFFS personnel stated that the aircraft burst into flames shortly after it landed on the motorway. A witness driving a large vehicle on the motorway stated that the pilots got out of the aircraft before it burst into flames and that the fire started about 15 to 20 seconds after it came to rest. Other witnesses confirm that the aircraft suddenly became engulfed in flames, and that before the large fire, an aircraft engine was on fire. An occupant of one of the damaged cars also reported a strong smell of fuel. One of the cars involved in the accident also caught fire.

1.14.2 Fire service response

On the day of the accident the RFFS were carrying out routine checks in preparation for the normal airport opening at 0600 hrs. At 0531 hrs the duty air traffic control officer contacted the airport Duty Fire Officer (DFO) and informed him that an aircraft was expected to land shortly, before the official airport opening. The Oxford and Southampton airport authorities had both given written permission for G-JETB to operate outside normal operating hours; this was dependent on the crew's acceptance of the fact that there would be no fire cover available and is allowable for a private flight. At the time the DFO was contacted, both fire vehicles (FIRE 1 and FIRE 2) were fully manned with three crew on each and only required check runs prior to coming on line. As they began these runs on the northern taxiways, the DFO, on FIRE 1, was monitoring the airport tower frequency and heard the ATC controller advise the crew of G-JETB that they would be landing with a 15 kt tailwind on a very wet runway. The DFO then ordered both fire vehicles to 'Weather Standby'; this is a precautionary action during adverse weather conditions and involves positioning the fire vehicles on the taxiway at right angles to the runway and approximately $^2/_3$ along Runway 20 (see Appendix E).

The DFO watched the aircraft land normally but saw it continue at high speed past his 'Weather Standby' position. Following clearance from ATC both fire vehicles entered the runway to follow the aircraft. As the aircraft slid off the side of the runway and disappeared from his sight the DFO ordered the driver of FIRE 1 to follow the aircraft tracks, and ordered FIRE 2 to proceed off the airport to the motorway. At the end of the runway, FIRE 1 was stopped to enable 4-wheel drive to be engaged, and the driver then followed the aircraft tracks to the edge of the embankment; the DFO stated that he saw a fireball some 5 to 10 seconds after the aircraft disappeared from sight and that it was a further 25 seconds before FIRE 1 reached the top of the embankment. On arrival, the DFO saw the aircraft on fire, one car upside down, and one other car with fire coming from its engine compartment. Using a side hose, the DFO concentrated on containing the fire around the cockpit area, and the monitor from FIRE 1 was used on the rest of the aircraft fire; the monitor extinguished all but a small amount of fire under each wing.

By now both pilots were clear of the aircraft, and the RFFS had confirmed that there were no other occupants in G-JETB. The DFO checked that both cars were empty and then extended his side hose to extinguish the car fire. Some 3 to 4 minutes after the aircraft left the runway, FIRE 2 arrived on the motorway at the scene and extinguished the residual fires, including what they described as a magnesium fire, i.e. burning with a very bright light, underneath the left wing by the landing gear; this was tackled with dry powder. Both fire vehicles continued to utilise foam and water to cool the aircraft, cars and the immediate area. It also became apparent that electrical power was still live on the aircraft and it took some time to isolate the batteries. By 0540 hrs the local police and rescue services began arriving and took charge of the situation.

The county firefighting services provided backup, but used only water by way of preventing further outbreaks of fire. The airport appliances used approximately 1,000 litres of foam concentrate, 13,000 litres of water and 2 kg of dry powder and did not run short of any firefighting medium.

1.14.3 Fire damage to aircraft

The aircraft came to rest pointing approximately 30° to the right of the wind direction. This had the effect of sparing the outboard left wing and the left side of the fin and rudder from the fire.

The fuselage had suffered severe fire damage in that areas of skin had been burned away, although the frames and stringers had largely survived, thereby preserving much of the structural integrity. One of the worst affected areas of the fuselage was on the left side of the cockpit, at the rear of the circuit breaker panel. It is possible that this was partly due to electric power still being present in the circuit breaker panel before the battery was disconnected, and that this helped to sustain the fire in this area.

The interior of the aircraft was extensively smoke blackened, with most of the fire damage being confined to an area close to the emergency exit. This appeared to be a consequence of the external fire entering the cabin, and there was evidence of a similar nature on the left side of the cockpit where fire had penetrated around the circuit breaker panel and the open DV window.

Away from the doors, the cabin furnishings had not burned, although plastic items such as trim panels and coat hangers had been badly distorted, thereby indicating the intensity of the heat within the cabin.

1.14.4 Fire damage to the car

The fire in the Renault was largely confined to the engine compartment. Examination revealed that the frontal impact damage had resulted in the down-draught type carburettor being knocked off its mountings. This may have allowed fuel to be sprayed onto the exhaust manifold located below, and hence could have initiated the fire. There was no charring on the road surface linking the car and the aircraft, which were approximately 15 metres apart; it was therefore concluded that the fires in the vehicle and the aircraft were initiated separately.

1.15 Survival aspects

1.15.1 Aircraft

The co-pilot left the cockpit first and attempted to open the normal exit door. He reported that he could only move the operating handle through approximately $^3/_4$ of its available movement even though he tried several attempts. The commander operated the emergency exit without difficulty and both pilots successfully vacated the aircraft. The commander then realised that the engines were still going and went back inside the aircraft to close them down. However, subsequently it was found that the right engine had not been not closed down completely and continued to run. The co-pilot stated that when he was outside the aircraft he became aware that the commander was not with him but, as he re-entered the aircraft he met the commander and they both left the immediate area towards the fire vehicle located at the top of the embankment.

The substantially intact condition of the aircraft together with the lack of injury to the crew provided an indication of the relatively small magnitude of the impact forces. However, as noted in paragraph 1.12.3.4, there must have been a significant vertical acceleration in order to trigger the inertia switches. The crew seats had not been mechanically damaged in the accident, although it was noted that the right-hand floor rail of the left seat had been deflected downwards at the point where it had been in contact with the rear roller.

1.15.2 Vehicles

The three occupants of the cars involved in the accident vacated their vehicles without major difficulty; all suffered minor injuries.

1.16 Tests and research

1.16.1 Testing of the anti-skid components

The wheel transducers, anti-skid valve and electronic control box were all manufactured by the Hydro-Aire division of the Crane Company of Burbank, California. This was the only location where these components could be bench tested and this was duly carried out under AAIB supervision.

a) Wheel transducers

The left-hand unit was visually in a good condition and was easily removed from the axle. The right unit had suffered some abrasion damage when the right landing gear became detached, and force had to be used in order to remove the transducer from the axle. Despite this, the unit met the production test requirements. The left-hand transducer also met the requirements, although the voltage signal became slightly erratic at low RPM; this was thought to be indicative of a worn bearing and was judged to have had no effect on the operation of the anti-skid system.

b) Valve assembly

This had suffered some blackening in the fire, and, as a result of damage to the nosewheel bay, had remained attached to the airframe only by one of the hydraulic lines. The test schedule included a variable electrical input (to simulate that normally provided by the control box) against which was recorded the brake release pressure. The results showed that the unit was only marginally out of specification and would have provided satisfactory anti-skid protection. Further confidence was provided by an additional test, not in the schedule, which tested that the unit was capable of brake release at relatively low pressures. (Such a test would show that the unit was capable of modulating at relatively low brake pressures, thus simulating conditions that might be experienced on a slippery runway surface).

c) Electronic control box

This unit had been blackened in the fire and the casing had been slightly damaged during the salvage. Despite this, the unit performed satisfactorily when subjected to the production test on the bench. Internally, the circuit card showed no evidence of fire or mechanical damage.

1.17 Additional information

1.17.1 Aerocharter (Midlands) Ltd company manuals

The crew were required to operate the Citation in accordance with the standard operating procedures and guidance written in the Aerocharter Operations Manual

(OM) and the Citation II Flight Manual (FM). In the pre-amble the OM (copy number 6) states that:

> 'The regulations and procedure promulgated in this operations manual are mandatory and have been compiled to obtain maximum productive capacity commensurate with safety and economy of operation. The maintenance of the standards so established is the responsibility of all Company Personnel.'

The OM also included the following instructions:

> 'The Captain has complete authority to take overriding and final decisions regarding any aspect of an operation which, in his opinion affects his performance to accepted safety standards.
>
> When a second pilot is carried, he is responsible to the Captain for monitoring landing procedures and it is his "express duty" to bring to the attention of the Captain any irregularity he notes in the operation of the aircraft.
>
> Before any flight the Captain will ensure that sufficient fuel and oil for the planned flight are on board and certified in the technical log and that a copy of the technical log is left at the airfield of departure.
>
> Do not take-off or land in areas of severe weather. It is very dangerous to attempt to take-off or land when thunderstorms lie in the immediate vicinity of the take-off or landing path. Cancel, delay or divert.
>
> Maximum tailwind component is 10 kt.
>
> When carrying 8 male passengers a minimum of 160 lb must be carried in Bay D (rear bay).
>
> If there is a tailwind on landing, the quick reference performance tables may not be used; in that situation a full calculation must be made from the FM.'

It was noted that 'actions in the event of a forced landing' were contained within the 'Limitations' section of the OM and not within the 'Emergency procedures checklist' section.

The FM included the following instructions:

> 'The maximum tailwind component for takeoff or landing is 10 kt.
>
> To obtain maximum braking performance from the anti-skid system, the pilot should apply continuous effort (no modulation) to the brake pedals.
>
> The performance information in the manual is not valid if any limitation is not observed.'

The sea level landing field length limit based on a landing weight of 12,500 lb, at an OAT of 12°C, no runway slope, at V_{REF} of 108 kt, and with a tailwind component of 10 kt (no figures given for a higher tailwind) was calculated from the FM as 5,554 feet (1,692 metres).

1.17.2 Tyre wear limitations

Guidance on tyre wear is given in the CAA's Airworthiness Notice No 5, issued in April 1972. This notes that BCARs demand that for certification of new types of aircraft, the depth of tyre tread below which wet braking friction characteristics are impaired should be specified at the time of certification. It is also required that it should be possible to determine, in operational conditions, when the tread depth is worn below this limit. The Notice contains a recommendation to the effect that a tyre be withdrawn from service when it is worn to the extent that its wet runway performance would be seriously impaired. This is defined as:-

(i) it is worn such that any groove has a depth of less than 2 mm of tread for more than one quarter of the tread circumference,

or

(ii) at any place on the circumference the tread pattern is worn to a depth of less than 2 mm across the whole width of the tread in contact with the runway.

NOTE: This is not a rigid definition and equivalence may be provided if, for example, tyre wear is such that whilst one groove is less than 2 mm all the others are 3 mm or more.

1.17.3 Factors affecting hydroplaning

Tests on the anti-skid equipment confirmed that all components were capable of operating normally. Thus, in the event of hydroplaning resulting in locked wheels at low brake pressures, the brakes would release completely until the wheels regained RPM. Hydroplaning is a dynamic process in which the tyre is partly or completely supported by a water film. Only the portion of tread area that is in direct contact with the runway surface can transmit horizontal forces for braking purposes. If the water film extends across the entire tyre footprint area, then the horizontal force, and hence the wheel spin-up moment, reduces to zero. In extreme cases, the pressure in the bow wave ahead of the tyre can cause the spin-down of an unbraked wheel. In such cases, there is a loss of directional control, i.e. steering, as well as a total absence of braking action.

It is generally accepted that there are two types of hydroplaning; dynamic and viscous. In the former, pressure generated in overcoming fluid inertia immediately ahead of the tyre/runway contact zone can support the tyre vertical load. The latter results from a thin fluid film preventing dry contact between the tyre and the surface within the contact zone.

In the event that a wheel becomes stationary, either by failure of the brakes to release, or from spin-down, then it is probable that energy dissipated in the contact area is capable of flashing the water film into steam, eventually leading to 'scalding', or areas of reverted rubber on the tyre.

Research into the phenomenon of hydroplaning has been conducted over the last 30 years or so and has investigated the factors influencing the hydroplaning speed V_P. One report on the subject, NASA Technical Note TN D-2056 (Phenomena of Pneumatic Tire Hydroplaning, by Walter B Horne and Robert C Dreher), derives an expression for the hydroplaning speed, simplified to the following:

> $V_P = 9\sqrt{P}$ kt, where P is the tyre inflation pressure in pounds per square inch (psi).

Note that this applies only to smooth tyres, or for treaded tyres where the depth of water exceeds a critical value which corresponds to the volume of water that can be accommodated in the tread grooves.

Thus for a nominal inflation pressure for a Citation mainwheel tyre of 108 psi, $V_P = 94$ kt approximately.

Information supplied by the tyre manufacturer (Goodyear) summarises other research which has attempted to quantify the effects of tyre groove depth, and the number and width of grooves relative to the total tyre width. The results indicate that an unworn tyre can reach full hydroplaning on an ungrooved runway when the water depth exceeds 5 mm. Tyre wear can lead to a marked reduction in braking action when the tread grooves reach approximately 2.5 mm.

The type of runway surface also has a major effect, i.e. grooved or smooth, asphalt or concrete. Perhaps less obvious is the effect of runway shape. Studies conducted by the UK Ministry of Defence have indicated that water build-up during heavy rainfall can be less on a domed runway (i.e. where the centre is higher than the edges) compared to one with an edge-to-edge cross-fall. Southampton runway is in the latter category, with drains installed along the eastern edge of the paving.

1.17.4 Estimated braking performance

Estimation of the braking performance was hampered by the lack of hard evidence of aircraft speed during the landing ground roll; from CVR evidence the threshold speed was probably between 110 kt and 120 kt IAS, giving a touchdown speed of between 105 kt and 115 kt IAS. This corresponds to a groundspeed of between 120 kt and 130 kt, assuming a tailwind of 15 kt as reported by the Control Tower.

The touchdown point has been estimated from witness reports as being in the area of the PAPIs, i.e. 267 metres from the threshold. From the position of ground marks as the aircraft left the side of the runway it was possible to make an estimate of 1,264 metres ground roll from the touchdown point. However this only covers the period from touchdown to where the aircraft left the side of the runway at an estimated speed of 50 to 60 kt. The aircraft continued a further 233 metres after leaving the runway to the top of the motorway embankment.

A performance model was derived from the dry runway performance figures supplied by Cessna and Appendix C, Figure C-2 shows stopping distance assuming a given touchdown speed. Joint Airworthiness Requirements (JARs), which superceded BCARs for later aeroplanes, although not used for certification of this aircraft, give factors to calculate a wet runway coefficient from the dry runway values, as defined in JAR 25AMJ 25X1591, Table 1. The wet mu values shown in Appendix C, Figure C-1 were derived from the dry mu values supplied by Cessna by applying the JAR factors. These figures were then used to calculate wet runway stopping distances from the measured dry landing figures supplied by Cessna. The wet runway stopping performance is shown in Appendix C, Figure C-2. The speeds quoted are IAS and, to convert to groundspeed, a 15 kt tailwind was assumed. For a touchdown speed of between 105 kt and 115 kt IAS, the distance required to reduce to 50 to 60 kt IAS is between 600 metres and 1,000 metres on a dry runway, and between 1,100 metres and 1, 800 metres for a wet runway. The Flight Manual distances which include a factor of 1.92 on the dry runway figures are also plotted on Figure C-2.

The figures presented here all assume LAND flap throughout, however, there was also the possibility of selection of Take-off/Approach flap during the later stages of the ground roll. Figures supplied by Cessna indicate that the landing ground roll distances for the Take-off/Approach flap configuration would be between 3% and 7% less, due to the greater wheel reaction force.

1.17.5 UK standards for measuring and reporting wheel braking action on wet runways

The UK Aeronautical Information Publication (UK AIP) states that the inherent friction characteristics of a runway surface deteriorate only slowly over a period of time, but that the friction of a runway surface and thus the braking action can vary significantly over a short period in wet conditions, depending on the actual depth of water on the runway. Also, long term (six monthly) seasonal variations in friction values may exist. The consequences of combinations of these factors is that no meaningful operational benefit can be derived from continually measuring the friction value of a runway in wet conditions. In the context of these paragraphs a 'wet runway' covers a range of conditions from 'damp' to 'flooded', as described below. It does not include ice or runways contaminated with snow, slush, or water associated with slush.

The condition of a wet runway is determined by the airport operator and notified to pilots by ATC, using the following terms and descriptions:

Damp:	The surface shows a change of colour due to moisture.
Wet:	The surface is soaked but no significant patches of standing water are visible.
Water patches:	Significant patches of standing water are visible.
Flooded:	Extensive standing water is visible.

The UK AIP states that when a runway, other than one notified as liable to be slippery when wet, is reported as damp or wet, pilots may assume that an acceptable level of runway wheel braking friction is available. When a runway is reported as having 'WATER PATCHES' or being 'FLOODED', wheel braking may be affected by hydroplaning and appropriate operational adjustments should be considered.

1.17.6 Airport information

1.17.6.1 Regulations

Civil Air Publication (CAP) 168 details the licensing regulations for airfields involved in all types of flying operations, particularly Public Transport (PT) flights. The licence for Southampton includes authority for PT flights. Additionally, under the terms of the Town and Country Planning (Aerodromes and Technical Sites) Direction 1992 for England and Wales and the Town and Country Planning (Aerodromes) (Scotland) Direction 1982, the Civil Aviation Authority (CAA) safeguards certain important aerodromes against future developments which might prejudice their actual or potential use for aviation purposes. In such cases the CAA issues an official safeguarding map which is deposited with the local planning authority or authorities around the aerodrome and with certain other bodies. The CAA has deposited such a map for Southampton, however, the safeguarding system generally relates to heights of structures which might adversely affect clearance heights.

One other requirement for local authorities under the latest Directions is for them to consult the CAA before granting planning permission for the development of land within areas designated as Public Safety Zones (PSZ) at civil aerodromes. Such zones are established by the Department of Transport at specified major airports in order to prevent any build-up of population in areas where there is a greater risk of an aircraft accident. Since 1982 a PSZ has generally been established at airports which have reached a minimum of 1,500 and have a potential for 2,500 PT movements per month; a standard PSZ is 1,000 metres long, orientated from the end of the runway. In 1977 Southampton (Eastleigh) Airport had a total of 3,750 movements per month, of which just over 900 were

PT flights. Although the airport has been kept under review since 1979, there is no PSZ yet established at Southampton. The latest figures for 1992 show a total of 53,499 movements (4,458 per month) of which 19,039 (1,586 per month) are Public Transport.

1.17.6.2 History

Southampton (Eastleigh) Airport was acquired by BAA plc in 1991. The final portion of the M27 motorway, which is adjacent to the airport, had been planned and built between 1969 and 1983; the motorway is 88 metres from the end of the runway. Following public inquiries held in 1969 and 1971 at which the possible effect of the motorway on the operation of the airport was debated at length, the line of the motorway was fixed in 1971. During these deliberations the safety aspects were considered in depth, the declared runway length was reduced, and various other options were considered to minimise any risk to the public. These included: diverting the motorway; building a portion of the motorway below the surface; installing a ground arrester system; and even closing the airport. However the final decision was based on the perceived minor risk of an accident on the motorway against the considered alternative of closing the airport; this risk was calculated as one accident in 70 years occurring on the motorway, although it was acknowledged that an accident could possibly occur within the first 20 to 30 years of operation. Prior to the accident to G-JETB, a Lockheed Jetstar also overran Runway 20 on 27 November 1992; on that occasion the aircraft came to rest 75 metres beyond the runway, but within the RESA and short of the motorway. (See AAIB Bulletin 3/93)

In 1976 there was a further inquiry at which the line of the motorway just west of the airport was reconsidered; this was not for reasons associated with the airport. In 1977 the question of the motorway proximity to the Airport was raised by a member of the public, however, after further consideration of the available options, the decision was taken, in 1978, to adhere to the original route. The question of a PSZ for the airport was also suggested and by 1979 the Department of Trade had included Southampton as one of the airports constantly under review for a PSZ.

The section of motorway adjacent to the airport was completed by the end of 1983. Although the option of a ground arrester system between the runway and the motorway was not progressed, this still remains as a possible solution to minimise the risk of damage resulting from an overrun.

1.17.7 Arresting systems

Trials were carried out in the late 1960's and early 1970's to establish if military aircraft could be successfully and safely arrested by a soft ground arrester bed in the overrun of a runway. Initially these trials were based on fighter type military aircraft, but in 1973 full size trials using a Comet aircraft were carried out at the Royal Aerospace Establishment (RAE) Bedford. The results were encouraging, although some problems still needed resolving when the trials were halted. Since then, the Federal Aviation Authority (FAA) in the USA have also been investigating soft ground arrester systems; during 1993 they conducted full-scale tests using a Boeing 727 in a phenolic-foam arrester bed. At present, in the UK there are four civilian airfields with a soft ground arrester bed. During the course of the investigation these airfields provided the following information on their experiences with the arrester beds:

1. Gloucester Airport The bed was installed in 1965 due to the groundslope beyond the end of the runway. The substance used is Sintered Fuel Ash Pellets (Lytag) and covers an area of 47 metres by 37 metres. It has never been used in anger and the only maintenance required is weed killing. The airport has a problem with jet blast from the reciprocal runway and recommends a gap of approximately 60 metres between the paved surface and the arrester bed.

2. Manchester Airport The bed was installed in 1982 following a runway extension; this runway extension resulted in a 25 metre drop at the end of the RESA. The substance used is Lytag and covers an area of 90 metres by 92 metres displaced 60 metres from the runway end. The bed has never been required for emergency use and the only maintenance needed is regular raking. The airport reports no major disadvantages with the arrester bed.

3. Southend Airport The bed was installed before 1980 due to the proximity of a railway line to the end of the runway. The substance used is Lytag and covers a horizontal area of approximately 37 metres by 10 metres; the bed slopes up away from the runway at 30° to a height of approximately 4 metres. It has never been required for emergency use and the only maintenance needed is a total agitation every two years. The airport reports no disadvantages but considers that the fine mesh netting used is essential to keep the Lytag in place.

4. Jersey Airport The bed was installed in 1975 because of a steep incline at the end of the airfield. The substance used is beach shingle; the bed is approximately 33 metres long, tapering in width from 93 metres to 46 metres and is located 46 metres from the runway end. There is a regular inspection of the area to note any settling or weed growth which could bind the surface. If this is noted, hand and/or machine raking is used to loosen the texture. The arrester bed was used in 1977 when a Viscount aircraft overran Runway 27 and was stopped without damage in the shingle.

1.18 New investigation techniques

Nil.

2 Analysis

2.1 General

The commander and co-pilot had both previously landed at Southampton (Eastleigh) Airport and were properly qualified and adequately experienced for the flight. The aircraft was free from defects, was below the maximum certified landing weight, and landed with a reported tailwind component of 15 kt on a very wet runway. The information relating to the runway landing distance available, the maximum permitted weight for landing in wet conditions, and the wind limitations were available to the crew. They had also been passed recent weather observations, including the warning of thunderstorms and the surface wind. This analysis considers the condition of the runway, the performance and braking effectiveness of the aircraft, the crew procedures including human factors aspects, airfield safety measures, and the reaction of the rescue services.

2.2 The runway surface

The runway surface was reported by the air traffic controller to the crew prior to landing as "VERY WET". This was based on the controller's view of the runway and his awareness of the rain intensity. The fire crew who followed G-JETB along the runway also stated that the runway was wet with heavy rainfall. Although the runway braking action was checked at 0628 hrs on 26 May 1993 and found to be good in all areas, this measurement was done 54 minutes after the accident and no rain had fallen in the intervening period. Therefore, the braking action at the time of the accident would have been less than that at the time the measurement was taken. The amount of precipitation is subjective but the evidence of witnesses indicates the existence of substantial water on the runway.

2.3 Aircraft braking performance assessment

From CVR evidence the threshold speed was probably between 110 kt and 120 kt IAS, giving a touchdown speed of between 105 kt and 115 kt IAS. This corresponds to a groundspeed of between 120 kt and 130 kt, assuming a tailwind of 15 kt.

Figures supplied by Cessna state that the maximum kinetic energy which can be absorbed by the brakes at a landing weight of 12,500 lb corresponds to a maximum brake application groundspeed of 112 kt; therefore had the brakes been applied above 112 kt, the aircraft could not have stopped on a dry runway from purely brake energy considerations.

It was not possible to determine the actual braking performance; however using the corrected wet runway mu, the braking performance was estimated. The distance required for the aircraft to stop for a given touchdown speed using this corrected wet runway mu was calculated. A comparison of this distance, and both the unfactored dry distance to stop calculated from mu supplied by Cessna, and the factored Flight Manual ground roll distance is shown in Appendix C, Figure C-2. It should be noted however that these distances all assume a tailwind of 15 kt (which is beyond the Flight Manual limit) and only estimate ground roll distance, whereas the figures for landing distance quoted in the Flight Manual include an airborne distance.

Appendix C, Figure C-2, shows landing ground roll as a function of touchdown IAS in the conditions pertaining at the time. From this it can be seen that, for a touchdown speed of between 105 kt and 115 kt IAS, the distance required to reduce to 50 to 60 kt IAS is between 600 metres and 1,000 metres on a dry runway, and between 1,100 metres and 1,800 metres for a wet runway.

The distance from touchdown, at between 105 kt and 115 kt IAS, to the departure of the aircraft from the side of the runway at around 50 to 60 kt IAS was estimated to be 1,264 metres. This value is within the wet runway mu estimate of between 1,100 and 1,800 metres, dependant on touchdown speed. It would therefore appear that the aircraft achieved the estimated braking performance, and there was no evidence of hydroplaning, within the accuracy of the available evidence.

The estimated distance required to stop from touchdown as shown at Appendix C, Figure C-2, is between 1,320 and 2,060 metres, depending on touchdown speed, and therefore it can be seen that the aircraft probably could not have stopped in the landing distance available.

The worn condition of the left tyre is more difficult to quantify in terms of its effect on the stopping distance of the aircraft. Allowing for the effects of the fire, the amount of tread groove depth remaining was assessed as being no more than 1 to 2 mm, and was probably worn in excess of the limits described in Airworthiness Notice No 5. Research into hydroplaning has indicated that there is a marked reduction in braking action when the tread depth is below 2.5 mm. In addition, the hydroplaning speed would have been around 94 kt from consideration of the typical tyre pressures. Thus, as the tread grooves filled with water in the deeper puddles on the runway, there would have been a tendency for hydroplaning, resulting in a reduction in wheel RPM followed by the anti-skid system releasing brake pressure. In such conditions, it is the most worn tyre that is the dominant influence on the braking action.

The preceding paragraphs have indicated that the aircraft could not have stopped in the available distance, purely from a performance consideration. Thus, unworn tyres would not have prevented the accident. However it is probable that improved braking action from less worn tyres would have resulted in the aircraft leaving the runway at a reduced speed.

2.4 Crew performance

2.4.1 General

It is acknowledged that a high proportion of air accidents involve human factors to some degree. In this accident there have been no identifiable failures related to the aircraft systems or to the airport. The crew were passed sufficient information to alert them to the need for caution and indeed the air traffic controller emphasised the surface wind in very clear language. Yet the crew persisted in landing the aircraft in conditions outside the aircraft limitations. Any assessments put forward in this report are necessarily subjective but advice was sought from a Principal Psychologist from the Royal Air Force Institute of Aviation Medicine. He worked with the investigating team in compiling the parts of this report that deal with human factors. The team were also fortunate in having the CVR available and this gives an insight into the working relationship of the crew, and their actions leading up to the accident.

2.4.2 Crew working relationship

The commander was a very experienced pilot who had been operating executive type aircraft for the last two years following his retirement from a major charter airline; he was primarily a freelance pilot but worked regularly for Aerocharter (Midlands) Ltd. The co-pilot, who was relatively inexperienced, was the chief pilot of a small company operating from Oxford. He had arranged the contract to ferry passengers between Southampton and Eindhoven each Wednesday. However he had also made a commercial arrangement with Aerocharter Ltd to the effect that Aerocharter Ltd would provide the aircraft and crew for some contracts that he would arrange, and would also check him out as a co-pilot on the Citation II; for the flights generated by himself, he would normally fly as co-pilot. For these particular flights it was normal for the co-pilot to make the ground and support arrangements; this would include paying the commander. Since at least January 1993, G-JETB had been used for the Southampton/Eindhoven flight with the co-pilot operating as second pilot. The commander had been operating the flight since March 1993. There was no doubt in the cockpit as to who was in charge of the flight but there was an unusual situation in that the co-pilot planned this particular aircraft operation and obviously had a major interest in the successful completion of the contract. From the commander's view, there would be the conflict between his command position and the realisation that his co-pilot was essentially his employer. From the co-pilot's view there would be the conflict between his secondary role in the aircraft, and both his normal role as chief pilot and his active organisation in the aircraft contract. Although both pilots had flown together many times, the CVR indicated that their working relationship was not particularly close. Nevertheless, the atmosphere was no worse than is experienced on many flight decks and the commander had the experience to cope with it.

2.4.3 Flight preparation

The crew were well rested prior to the flight and had not been working excessively in the recent past. The aircraft had arrived at Oxford the previous day and had been refuelled to full tanks; this fact was not entered into the technical log as required by the Operations Manual. Additionally the crew knew the expected passenger numbers (8 males) to be picked up at Southampton and a simple calculation would have highlighted the fact that the aircraft was going to be overweight for takeoff at Southampton. It was also noted that the Operations Manual requires 160 lb in the rear hold with the full passenger load that they were expecting and this would further increase the excess weight. Bearing in mind the fact that the passengers were intending to return the same day, and would therefore have minimal luggage, it is difficult to see how this requirement would be achieved without some planning for ballast; with the fuel state on board there was no flexibility to load this at Oxford and there was no indication of any plan to load ballast at Southampton. No doubt the excess weight would have been revealed on load sheet completion at Southampton but the situation indicates inadequate planning for a prospective PT flight.

2.4.4 Flight profile

The flight from Oxford to Southampton was not difficult and the crew were quickly aware of the weather conditions including the presence of thunderstorms. They carried out their duties adequately although there was arguably little evidence of camaraderie on the flight deck. The commander was not very communicative and there were occasions when he did not appear to hear incoming transmissions. The co-pilot was reasonably talkative and the lack of response from the commander did not appear to inhibit him. The crew's original expectation was that they would be making an approach to Runway 02 and the navigation aids were orientated for this approach; the weather had been passed to, and acknowledged by, the crew.

The first change occurred when the Southampton controller offered the crew the option of making an approach to Runway 20 enabling them to use the ILS facility;

this is a precision approach aid which is not available on Runway 02. However the controller also stated the need for a break-off at some stage for a visual circling procedure to position for a landing on Runway 02. The commander immediately accepted this option without any discussion with his co-pilot. At this stage it was a perfectly reasonable offer made to ease the pilot's task and accepted as such. The commander had no trouble establishing on the ILS approach and had mentally calculated the wind component along the runway as 'about 10 kt'. This was based on the previous winds that he had been given; on first contact the wind was given as 020°/14 kt, and shortly afterwards the wind was passed as 040°/12 kt. These two reports indicate a tailwind component along Runway 20 of 14 kt and 11 kt respectively; both are outside the aircraft limits.

2.4.5 Visual approach and landing

The commander achieved visual contact with the runway at a range of 4 nm. At that point he could see that the runway was wet and at the time he was not flying in rain. The approach was uneventful until the commander stated his intention to land on Runway 20. His reasoning was that he could see the runway clearly from his present position but that it appeared very black at the other end of the airport, the area he would have to fly into if he positioned to land on Runway 02. This was a valid reason for landing in a southwesterly direction, but obviously subject to the wind strength. He had also noted the wind component as 'about 10 kt'; this was the aircraft absolute limit for a tailwind landing but he was also influenced by his favourable experience in landing the Citation on other runways. When the commander made this decision the co-pilot asked him for confirmation. On receiving this confirmation the co-pilot passed the decision to the air traffic controller. The controller immediately replied that: "YOU'LL BE LANDING WITH A FIFTEEN KNOT, ONE FIVE KNOT TAILWIND ON A VERY WET RUNWAY". The co-pilot acknowledged this with a call of: "ROGER, COPIED THANK YOU".

There is no doubt that the crew had been informed very clearly of the wind and runway conditions and that the co-pilot had acknowledged this fact; the call of "ROGER" is a standard aeronautical term, as defined in the Manual of Air Traffic Services, meaning that all of the last transmission has been received. Neither crew member raised the question of wind limitations although both were aware of the 10 kt tailwind limitation, and indeed the limitation is common to many aircraft. The only possibilities are that the crew chose to ignore the limitation, or did not hear or assimilate the information. Subsequent to the accident the commander stated that he could not remember hearing the wind being passed at that time and the co-pilot could remember hearing the wind strength but not the direction although he was aware that there was a tailwind.

It was apparent from the CVR that, subsequent to the wind warning the co-pilot began to act in a more deliberate manner, which may indicate his increasing awareness that the situation was becoming more critical. There were sufficient warning signs that they would be landing close to, if not outside, limits and wind information was therefore of paramount importance. It is of note that the commander stated that he had landed the aircraft in tailwind conditions before and never had any trouble stopping. It is perfectly feasible that the commander had calculated his tailwind component as about 10 kt and, based on his previous experience, made his decision to land downwind. At that time he would have been concentrating on his approach, to ensure he landed as close to the end of the runway as possible, and this could explain why he did not note the final wind call.

It is worth emphasising that the Citation II can be flown single crew quite safely but that PT rules require a second pilot; the second pilot does not need to be qualified as a first pilot but is subject to the company regulations and the appropriate flying checks on the aircraft. The relationship between the crew members has been discussed before but the co-pilot is much less experienced than the commander and it could be argued that he should always accede to the commander's decisions. However the company manuals require both crew members to comply with the regulations. Furthermore the co-pilot's position as a chief pilot of another company and his interest in fulfilling the contract gave him a status above that of a normal co-pilot. He had a responsibility to question the commander's decision to land, not merely to ask for confirmation. Having made all of the radio calls and acknowledged the final wind call, he had the duty to bring the impending breach of regulations to the commander's attention or at least to ensure that the commander had heard the final wind call. The possibilities are that he did not appreciate the significance of the wind call or was submitting to the commander's greater experience. The only objective evidence bearing on this issue is the CVR and, on balance, it seems probable that the co-pilot was relying on the commander's judgement.

2.4.6 After landing

Following the landing it quickly became apparent that the retardation was insufficient. Both pilots were applying maximum foot pressure and there were no indicated warnings relating to the brakes or the anti-skid system. The commander considered two options: firstly to maintain full braking and try to maximise the ground roll, and secondly to go-around. The commander decided on the first option.

During the landing run the co-pilot called for a go-around on two separate occasions but the commander decided that a go-around at either stage would have put the aircraft in a more hazardous situation. The CVR indicates that the first call was made four seconds before the aircraft left the side of the runway; at this stage the aircraft was approximately 290 metres from the end of the runway and the engines would have been at idle power. Given the performance data provided by Cessna at paragraph 1.6.6, it is most unlikely that the aircraft would be capable of accelerating to V_R (103 kt IAS) within the distance remaining. The commander's decision not to go-around on either call was prudent.

When the aircraft was recovered, the flap handle was at the Take off/Approach detent and the flap drive motors indicate that the flaps were at the intermediate position. The crew were certain that the flaps were fully down for landing and this was supported by the trial flight indicating that the declared approach speed could not have been achieved without full flap. On the final approach the crew had discussed their actions in the event of a go-around and had briefed that the co-pilot would select take-off flap. Shortly after the accident both pilots were adamant that they had not touched the flap handle during the ground run or during their exit. A few days later the co-pilot found a bruise on the underside of his left arm that had obviously been caused by contact with a solid article and surmised that he could have hit the flap handle during his evacuation. This is considered unlikely because of the downward movement required to move the lever out of a detented position and the physical damage sustained by the flap operating system by the time it reached the motorway (see paragraph 1.12.3.2). The most likely scenario to explain the final position of the flaps would be that the co-pilot selected the take-off position as he made his call for a go-around; although he stated that he did not touch the flap lever on the ground roll, it would be a normal response to do so and not subsequently recall the action. However, the selection of Take off/Approach flap at this stage would have had a small beneficial effect on ground roll.

2.4.7 Evacuation

Once the aircraft left the runway, the crew had little control over the subsequent events. There is no doubt that this would have been a traumatic event and the crew would have been in a state of shock when G-JETB finally came to rest on the motorway. The crew evacuated the aircraft via the emergency exit, after unsuccessfully trying to open the normal exit. However, once the commander was outside the aircraft he realised that the engines were still running and re-entered the cockpit to attempt to close them down. In the event, he only closed one down correctly and the other kept running; it is probable that his unusual position of leaning into the cockpit to operate the engine controls caused this discrepancy in procedures. The right engine, which remained at idle, probably contributed to the severity of the fire. However, the commander, although taking a laudable action, put himself in increased danger by returning to the cockpit. It was noted that the evacuation drills were detailed in the 'Limitations' section of the Operations Manual but not in the 'Emergency' section.

2.4.8 Summary

The flight was not a demanding one and the crew had often flown the same route before. There were indications that the pre-flight planning was not very thorough and that the slightly unusual working relationship between the two crew members was a contributing factor. The crew were well rested and the weather was not particularly bad; they should have experienced no problems with this flight. Perhaps this fact lulled a very experienced aviator into a relaxed attitude and, allied to his confidence in the stopping ability of his aircraft, allowed him to ignore the danger signs and put his crew and the aircraft into a hazardous situation. The commander should not have attempted a landing on Runway 20 in the reported wind conditions, or even with the wind he had computed, and the co-pilot should have warned him that he was landing outside limits.

2.5 Airport Safety Aspects

As discussed in paragraph 1.17.6, public safety was considered in depth during the period when the portion of the M27 motorway, adjacent to the airport, was being planned and built. The declared runway length was reduced to maintain compliance with CAA licensing requirements in the light of the motorway development. Additionally, various options for provisions in addition to the licensing requirements, including a ground arrester system, were considered in order to minimise any risk to the public travelling on the motorway. None of these options appear to have been progressed. At the time the risk of an accident occurring on the motorway was assessed as one accident in 70 years, although it was acknowledged that one could occur within the first 20 to 30 years of operation. The accident involving G-JETB happened within 10 years. An earlier overrun accident at Southampton in November 1992 was also from Runway 20 but the aircraft stopped within the RESA and before reaching the motorway. Although human factors were a significant part in the G-JETB accident it would be impracticable to guard against all human errors. The proximity of the motorway to the runway increased the risk to the public, however, the degree of risk could be reduced by one of the options originally considered. As discussed in paragraph 1.17.7, ground arrester systems have been in existence at certain civil airports in the UK since 1965; on one occasion the system was used to stop a PT aircraft overrun with no damage or injuries. There are certain difficulties associated with the installation of such a system; for example it results in an additional hazard for aircraft undershooting an approach in the opposite direction and could cause terrain difficulties for rescue vehicles. Nevertheless, for the situation at Southampton the installation of a ground arrester system between the runway and the motorway would reduce the chance of injuries or damage resulting from any future overrun. The installation cost of such a system would be relatively minor compared to the overall airport operating costs, and the annual maintenance requirement would be minimal. It is therefore recommended that BAA plc and Southampton (Eastleigh) Airport, should install a ground arrester system between the threshold of Southampton Runway 02 and the M27 motorway [Recommendation 94-14]. In addition, since there may be other runways within the UK where a similar risk exists, it is also recommended that the CAA should review all UK licensed airfields to identify potential safety hazards beyond current RESAs and determine the need for, and practicality of, installing ground arrester systems [Recommendation 94-15].

Additionally, since the motorway was built, public transport movements at Southampton (Eastleigh) Airport have increased from 900 per month in 1977 to 1,586 per month in 1992. This number exceeds the minimum movements required for the establishment of a PSZ. Although the existence of a PSZ would not have prevented the accident and would not affect the present state of the motorway it would restrict any future population build-up, such as the building of a motorway rest/service area. It is therefore recommended that the Department of Transport should establish a PSZ at Southampton (Eastleigh) Airport [Recommendation 94-16].

2.6 Reaction of the Fire Services

It was apparent that ATC at Southampton were not aware of the expected arrival of G-JETB but the confusion was quickly resolved and the crew confirmed that no fire cover was required.

The reaction of the RFFS showed a high level of initiative in recognising the potential danger of the situation and a very rapid response in dealing with the accident. Their performance was a major factor in minimising the hazards to the flight crew and the public. The DFO maintained a close liaison with ATC and, even though some checks were not complete, positioned his fire vehicles in a position from which they could react most effectively. The vehicles followed the aircraft up the runway, and as the DFO saw it leave the runway, deployed his two vehicles. FIRE 1 followed the aircraft across the grass and FIRE 2 deployed via roads to go to the motorway. The flight crew of G-JETB did not appreciate the extent or severity of the fire. Various eyewitnesses remarked that the aircraft suddenly burst into flames after the crew had got out.

Despite the prompt arrival of the fire service, the aircraft was badly damaged by the fire. Had the accident occurred to a larger aircraft, it is doubtful as to whether a survivable cabin environment could have been maintained long enough to allow a complete evacuation.

The cause of the fire was not positively established. Despite the fact that the aircraft came to rest in a spreading pool of fuel with the engines still operating, the jet efflux was not directed at the fuel. The abrasion of steel components on the surface of the road probably gave rise to sparks before the aircraft came to a halt, although initially there would not have been large quantities of fuel around. It is considered that fire was most probably initiated electrically, with the landing light cables attached to the main landing gear legs being possible candidates. These cables are electrically 'live' when the landing gear is extended regardless of whether the lights are selected on. The fire services report notes a 'magnesium fire' under the left wing, which, in the absence of any magnesium alloy in this area, may have been an arcing process, or even the landing light filament becoming illuminted as a result of a random earth. The fact that the anti-collision beacon remained on until the battery was physically disconnected was an indication that electrical circuits remained energised after the battery master switch was selected 'OFF'.

Although the aircraft was equipped with inertia switches that shut down the CVR and activated the emergency cabin lights, there were no similar devices to shut down the engines and electric power. However, such devices are normally activated by forward and vertical deceleration, and so even if the aircraft had been so equipped, they would not have operated as a result of the aircraft sliding rearwards into the motorway barrier.

3 Conclusions

(a) Findings

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

(ii) The aircraft had valid Certificates of Airworthiness and Maintenance and had been maintained in accordance with an approved schedule.

(iii) The aircraft was below the maximum authorised landing weight and was correctly loaded.

(iv) The crew landed the aircraft in wind conditions which were outside the limits detailed in both the Flight Manual and the Operation Manual.

(v) The friction characteristics of the Southampton runway were satisfactory.

(vi) At the time of the accident it was probable that areas of standing water were on the runway with an associated reduction in braking effectiveness.

(vii) Examination of the aircraft's wheel braking and anti-skid systems after the accident showed them to be operationally satisfactory.

(viii) The worn condition of the left tyre probably reduced braking effectiveness in the wet conditions.

(ix) Braking performance analysis indicates that, in the conditions existing at the time of the accident, the aircraft probably could not have stopped in the runway available.

(v) Southampton ATC procedures were carried out effectively.

(vi) The anticipation and reaction of the Southampton RFFS was highly commendable and probably contributed to the minimal injuries of personnel.

(vii) The proximity of the motorway to the end of the runway contributed to the severity of the accident.

(b) Causes

The investigation identified the following causal factors:

(i) The commander landed with a reported tailwind of 15 kt which was outside the aircraft maximum tailwind limit of 10 kt specified in the Cessna 550 Flight Manual.

(ii) The co-pilot did not warn the commander that he was landing with a reported tailwind component which was outside the aircraft limit.

(iii) With a tailwind component of 10 kt, the landing distance available was less than the landing distance required.

4 Safety Recommendations

The following safety recommendations were made during the course of this investigation:

4.1 BAA plc and Southampton (Eastleigh) Airport, should install a ground arrester system between the threshold of Southampton Runway 02 and the M27 motorway. [Recommendation 94-14].

4.2 The CAA should review all UK licensed airfields to identify potential safety hazards beyond current RESAs and determine the need for, and practicality of installing, ground arrester systems. [Recommendation 94-15].

4.3 The Department of Transport should establish a Public Safety Zone at Southampton (Eastleigh) Airport. [Recommendation 94-16].

M M Charles
Inspector of Air Accidents
Air Accidents Investigation Branch
Department of Transport

May 1994

APPENDIX A

SOUTHAMPTON AIRPORT - RUNWAY 02/20

Mu-meter Test Results

Date: 4 June 1993
Condition: Good
Surface description: Brushed concrete
Rubber deposits: Light
Weather: Fine, sunny

Run No	Direction	Speed km/h	Dist from C/L	Self Wet	Mu-meter reading: Rwy 02 threshold end	Mu-meter reading: Centre third	Mu-meter reading: Rwy 20 threshold end
1	02	64	1m N	Off	0.82	0.81	0.80
2	20	130	3m N	On	0.57	0.56	*0.52
3	02	130	4m N	On	*0.55	0.57	0.55
4	20	130	3m S	On	0.56	0.59	*0.58
5	02	130	4m S	On	*0.56	0.57	0.59
6	20	130	10m N	On	0.60	0.60	*0.53
7	02	130	2m S	On	0.67	-	-
8	02	32	2m S	On	-	0.61	-
9	20	64	4m S	On	-	0.62	-
+10	02	97	5m N	max	0.54	0.54	0.52
11	20	64	1m N	Off	0.79	0.80	0.80

* Not full third - vehicle accelerating
\+ Carried out for purpose of comparison with US test methods

Averge 64 km/h dry reading (Runs 1 & 11):	0.80
Averge UK self-wet reading (Runs 2-5, full thirds only):	0.57

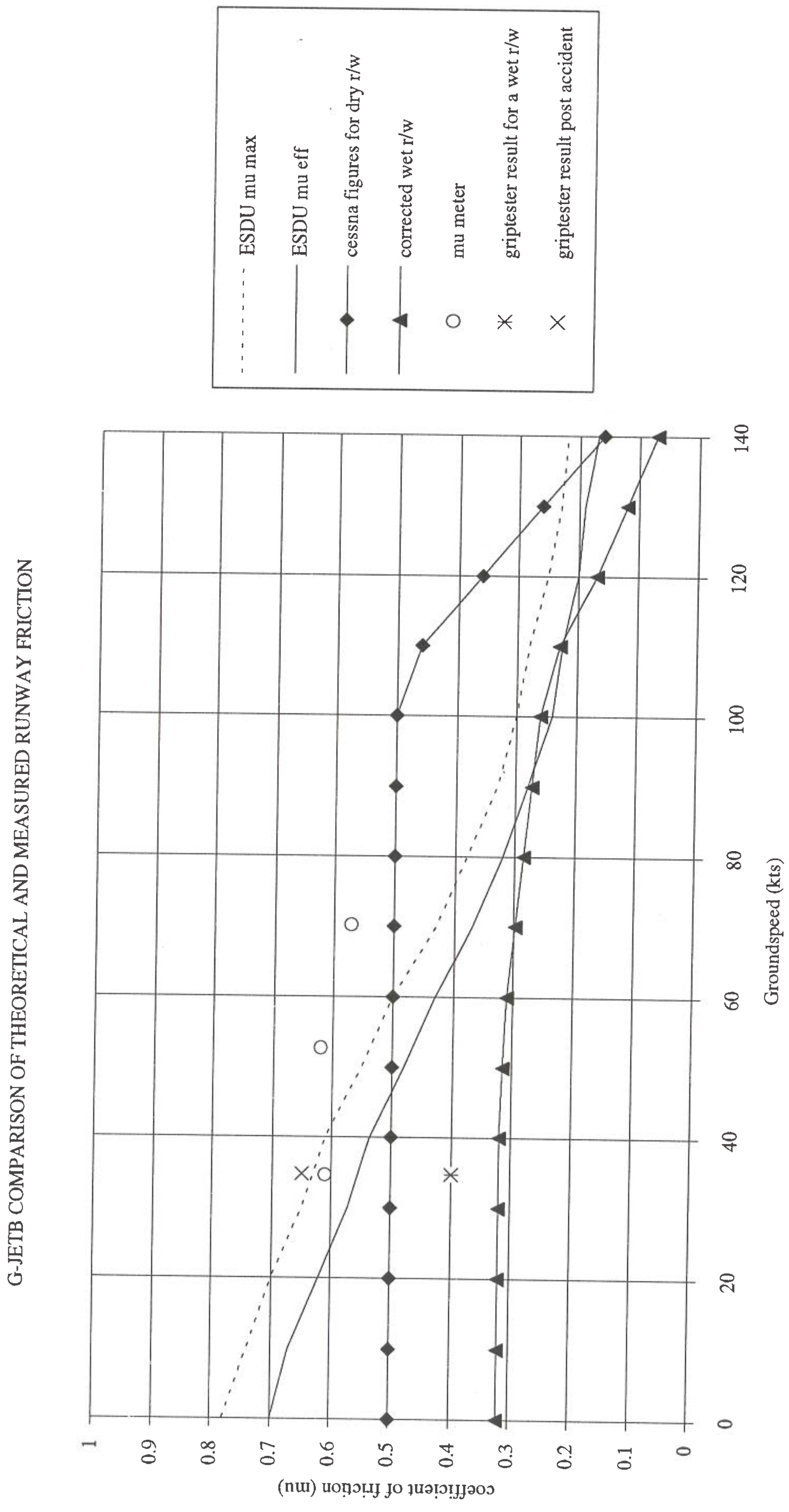

G-JETB COMPARISON OF THEORETICAL AND MEASURED RUNWAY FRICTION
ESDU mu max
ESDU mu eff
cessna figures for dry r/w
corrected wet r/w
mu meter
griptester result for a wet r/w
griptester result post accident
coefficient of friction (mu)
1
0.9
0.8
0.7
0.6
0.5
0.4
0.3
0.2
0.1
0
Groundspeed (kts)
0
20
40
60
80
100
120
140

Figure C-1

G-JETB GROUND DISTANCE REQUIRED TO STOP

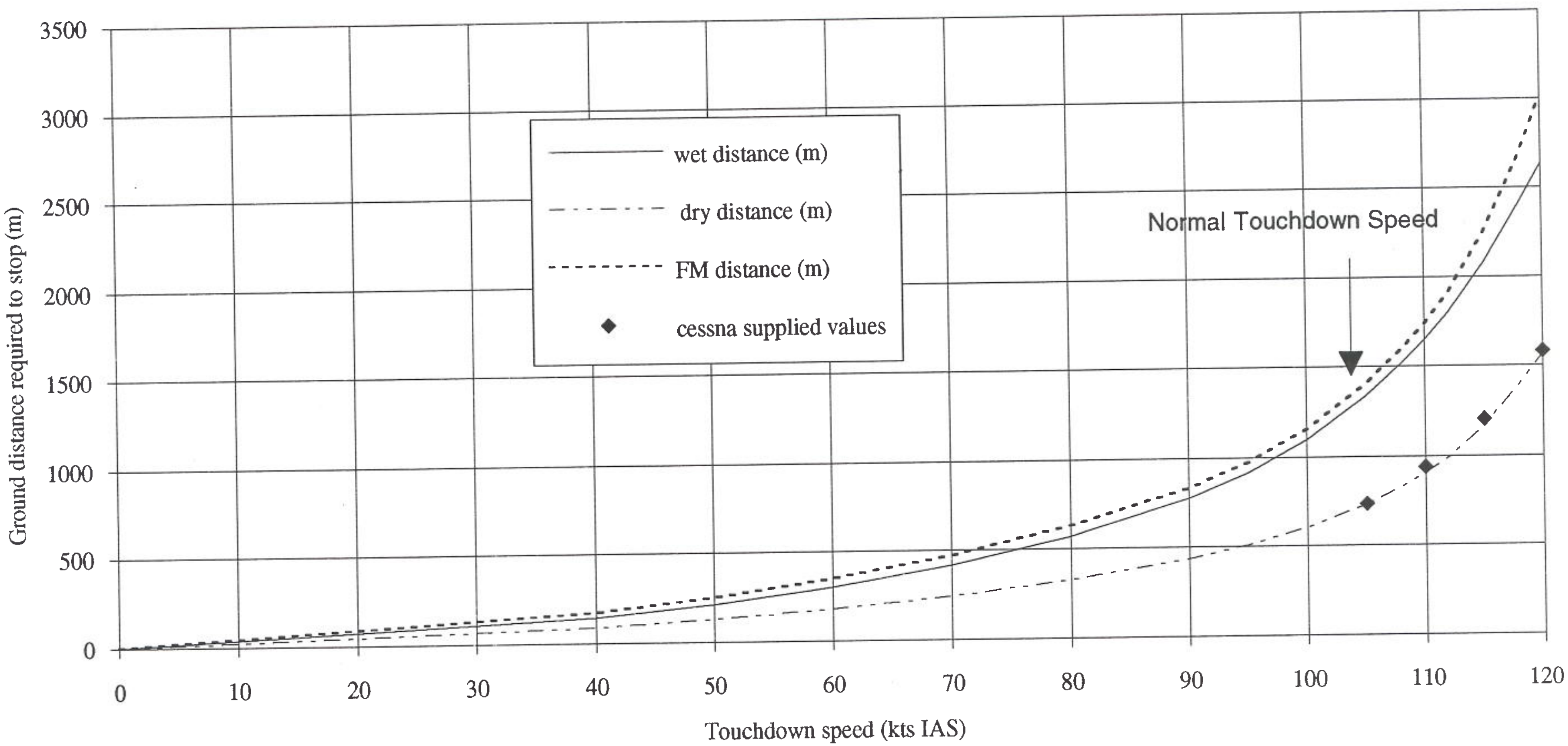
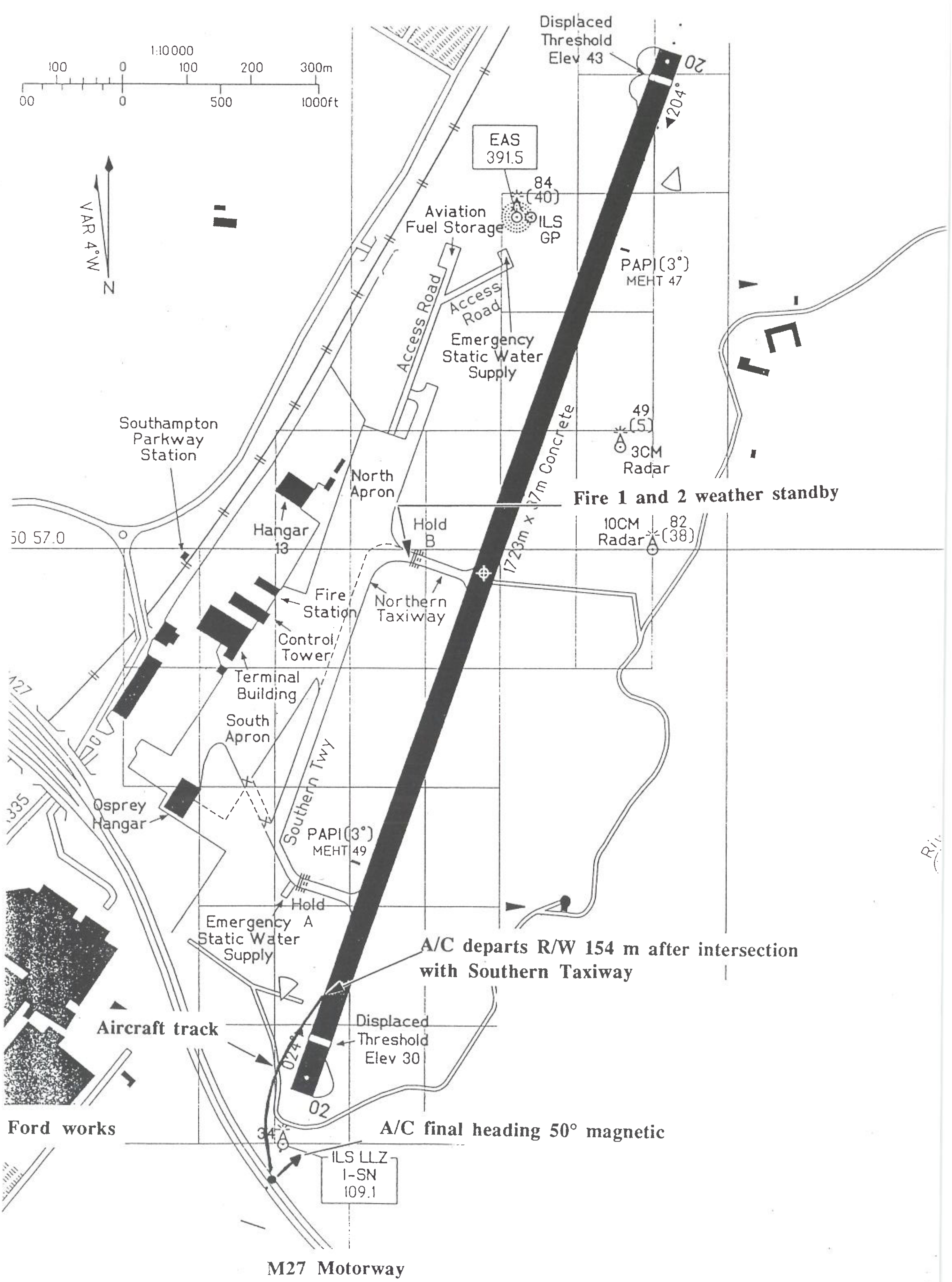


Figure C-2

LEFT TYRE

RIGHT TYRE



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