MINISTERIO DE FOMENTO
SUBSECRETARÍA

COMISIÓN DE INVESTIGACIÓN DE ACCIDENTES E INCIDENTES DE AVIACIÓN CIVIL

TECHNICAL REPORT

Accident occurred on 21 May 1998 to Aircraft Airbus A-320-212 Registration G-UKLL At Ibiza Airport, Balearic Islands

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WARNING

This Report is a technical document that reflects the point of view of the *Comisión de Investigación de Accidentes e Incidentes de Aviación Civil* (Air Accidents and Incidents Investigation Commission) regarding the circumstances that surrounded the event which is the subject of this research, together with its causes and consequences.

In conformity with the provisions of Annex 13 to the International Civil Aviation Convention and Royal Decree 389/1998 of March 13, which regulates the research on civil aviation accidents and incidents, this research is of an exclusively technical nature and it is not aimed at claiming or limiting rights or personal or financial liabilities. The research was conducted without necessarily using test procedures and with no basic aim other than preventing future accidents. The results of this piece of research do not condition or prejudge those of any possible punishing proceedings concerning the event that might be initiated under the provisions of *Ley de Navegación Aérea* (Air Navigation Act).

SYNOPSIS

During the cruise phase of the flight from Manchester to Ibiza, Autobrake Low was pre-selected for landing. Due to a computer logic channel discrepancy at the time of the selection, a 'BSCU Channel 2 Fault' was annunciated to the flight crew. The selection was repeated but the fault remained. Consultation with the aircraft's Flight Crew Operating Manual indicated that this was for crew awareness.

After a normal ILS approach, the aircraft landed on Runway 24 at Ibiza Airport. On touchdown, the Normal Braking system failed, but this was not annunciated to the crew as the warning is inhibited from touchdown until engines are shut down.

An Alternate Braking system should have been automatically available to respond to the crew's braking input commands. However, there had been an ingress of a small amount of water and detergent mixture into the Brakes Dual Distribution Valve at some time prior to the event flight. The water had frozen during the cruise phase and had not melted by the time of landing, such that the valve action was inoperative, and the Alternate braking system did not work.

The aircraft's Parking Brake system was available for use, but the flight crew had not been trained in its use in this manner.

The commander took control of the aircraft during the landing roll, as soon as he discovered that there was a braking abnormality. He applied maximum reverse thrust and attempted to swerve the aircraft from side to side in order to reduce the speed, but the aircraft left the end of the paved runway surface into the over-run area. The commander knew of the location of the airfield boundary wall at the runway extension and its proximity to the Mediterranean sea. He elected to turn the aircraft through some 90° to the right where the aircraft ran into a low earth embankment. The nose landing gear collapsed and the engines made contact with the embankment, bringing the aircraft to a stop.

An emergency evacuation was initiated and all main doors and escape slides functioned normally. The passengers did not deploy any of the four overwing exits. There was no fire and only minor evacuation injuries occurred.

1. FACTUAL INFORMATION.

1.1. History of the flight.

The aircraft was owned by GATX Leasing and operated by Leisure International Airways. In the event flight, the aircraft was operating a passenger holiday charter flight on behalf of Sabre Airways, flight number SBE-4064, from Manchester to Ibiza.

The flight deck crew were normally based at London Gatwick Airport and reported for duty there at 18.00 hrs UTC in order to be positioned by air to Manchester to operate the flight to Ibiza. The cabin staff were all based at Manchester.

On arrival at the aircraft, the commander noted that there were three items in the Deferred Defect section of the Technical Log, but these were not relevant to the flight or the subsequent event.

Boarding progressed slightly slower than normal, with the result that the flight departed at 22.30 hrs, some 15 minutes behind the planned schedule. Two pilots, five cabin crew and 180 passengers were on board.

After pushback and engine start, the crew noted a brief ECAM (Electronic Centralised Aircraft Monitoring) message: 'Digital Flight Data Recorder Fault', but this condition was only transient.

The take-off, departure and cruise phases were uneventful. The handling pilot for the sector was the first officer; this was decided during the pre-flight briefing, given the good meteorological conditions expected at destination.

As soon as the Ibiza METAR had been obtained, while still in the cruise phase, the first officer planned for an ILS approach to Runway 24, set up the navigation aids and programmed the Flight Management Guidance Computers (FMGC's) accordingly. He pre-selected the BSCU (Brake and Steering Control Unit) Autobrake system to Low. Upon this selection, a 'BRAKES BSCU CH 2 FAULT' was annunciated to the crew. There was no ECAM procedure to be followed. The selection was repeated but the fault remained. The Status Page displayed ‘Inop Sys BSCU2 Fault’ (‘Inoperative System, BSCU Channel 2 Fault’). The crew checked the relevant section of the Flight Crew Operating Manual Volume 3 and this stated that the indication was for 'Crew Awareness'. No further crew action was specified.

There were no further abnormal indications present. A normal ILS approach was conducted. The first radio contact with Ibiza approach at 119.8 MHz ocurred at 00.35 hrs. The aircraft was already established at ILS a 10 Nm from the VOR-DME of Ibiza-IBA. At 00.46:36 hrs they were authorised to land on Runway 24, wind of 020º direction and 5 Kts velocity.

The aircraft made the flare and a gentle touchdown about 800 metres from the start of Runway 24. A slight tailwind component was apparent, of approx. 4 kt. Reverse thrust was selected and initial deceleration appeared normal. The commander considered that more braking was required in order to slow the aircraft to achieve the planned turn off the runway, so he advised the first officer to apply more braking.

The first officer tried to apply more braking but found this ineffective. He informed the commander of this and, around 80 kt, the first officer reduced reverse thrust. The commander immediately took control, reapplied reverse thrust and attempted to apply the brakes. He too found that there was no braking available. Therefore, the commander began to swerve the aircraft each way in an attempt to increase the available braking distance and slow the aircraft down by lateral skidding before reaching the end of the runway, with the tyres leaving rubber marks on the runway surface.

The aircraft left the end of the runway, entering the paved stopway (SWY) and then into and beyond the 60-m overrun area (CWY). The commander was familiar with Ibiza Airport and knew of the presence of the aerodrome boundary wall and the Mediterranean Sea beyond it. He therefore elected to turn the aircraft to the right to remain within the aerodrome boundary. The nose landing gear collapsed as the aircraft ran on softer and more rugged terrain to approach an earth embankment and then came to rest with both engines partially embedded in it. The ride across the overrun area had been quite rough and much of the flight deck paperwork had become dislodged, including the charts and checklists.

When the aircraft had stopped moving, the flight deck was in total darkness. The commander and the first officer worked together to complete by recall all the items of Emergency Evacuation checklist. TWR were informed at 00.51 hrs and the emergency services were requested. A confirmation was given to the senior cabin crew member to initiate the evacuation.

The controller on duty noted that something was wrong and made four attempts to establish radio contact with the aircraft during the minute previous to the communication from the crew; he activated the emergency alarm before establishing radio contact. The Fire Service communicated with Tower about 10 seconds before crew confirmation; they were given the aircraft location and within about 30 further seconds they were on their way to the scene of the event.

The engines were shut down, but the fire extinguishers were not activated. On completion of the checklist items, the flight deck crew went back into the cabin, ensured that it was empty, then left the aircraft by one of the forward slides. There was no sign of fire

1.2. Injuries to persons.

INJURIES	FATAL	SERIOUS	MINOR/NONE
CREW	0	0	7
PASSENGERS	0	0	180
OTHER	0	0	

1.3. Damage to aircraft.

The nose landing gear had collapsed rearwards and was broken. It was found between the two main landing gear doors, which were open.

Both engine nacelles were distorted at the bottom and were partially embedded in an earth embankment. Both engines suffered damage from ingress of earth and stones. Both engine reverses were deployed. The flaps and slats were extended to the landing position.

The fuselage was generally undamaged, except for the bottom area adjacent to the nose landing gear. The two nose landing gear doors were also damaged.

All of the tyres showed signs of damage. The main landing gear tyres were still inflated, but both nose wheel tyres had deflated.

1.4. Other damage.

Several runway end lights and approach lights for runway 06 in the overrun area and beyond were damaged and required replacement.

Since the area in which the aircraft came to a rest was near the ILS booth, it was necessary to conduct test flights in order to check the quality of the ILS signal. It was confirmed that this radio aid was not affected.

1.5. **Personnel information.**

1.5.1. Commander.

Age / Sex:	49 years / Male
Nationality:	United Kingdom
Licence:	Airline Transport Pilot
Number:	AT/204524 J/A
Date issued:	02/04/1990
Instrument Rating:	
- Last base check:	24/11/1997
- Last line check:	03/07/1997
Medical certificate:	Class 1, 31/03/1998
Ratings:	
- Of aircraft Type:	A-320/A-321, B-737, Cessna Citation, Bae 125.
- I.F.R:	24/11/1997
Total flying hours:	10761
Total hours on Type:	656
Previous rest period:	51 hours
Hours in last 90 days:	135
Hours in last 30 days:	56
Hours in last 24 hours:	2

1.5.2. First officer.

Age / Sex:	29 years / Male.
Nationality:	United Kingdom
Licence:	Commercial Pilot's Licence.
Number:	CP/270056E/A
Date issued:	23/06/1997
Instrument rating:	
- Last base check:	11/03/1998
- Las line check:	14/04/1998

Medical certificate:	Class 1, 05/08/1997
Ratings:	
- Of aircraft Type:	A-320/A-321, PA-23/34/44.
- I.F.R:	04/03/1998
Total flying hours:	461
Total hours on Type:	115
Previous rest period:	48 hours
Hours in last 90 days:	115
Hours in last 30 days:	69
Hours in last 24 hours:	2

1.5.3. Cabin crew.

Four of the five cabin crew members had over four years flying experience. The fifth member was a recent recruit with three months flying experience. All five crew members had completed initial or refresher training within six months of the accident date and all of the crew certificates were in order.

1.5.4 Flight Deck Crew Training.

The commander completed his A-320 simulator training course on 7 April 1997. The first officer completed his A-320 simulator training course in March 1998.

Both pilots had been provided with personal copies of the A-320 FCOMs by the operator. The operator´s training syllabus followed the approved Airbus conversion course syllabus. The course followed the Flight Crew Training Manual, which did not include any reference to, or simulator training practice in, the use of the parking brake as an emergency stopping device.

1.6. **Aircraft information.**

1.6.1. Airframe.

Manufacturer:	Airbus
Model:	A-320-212
Constructor's number:	189
Date of manufacture:	1991
Registration:	G-UKLL
M.T.O.W.	77.000 Kg
Owner:	GATX Leasing
Operator:	Leisure International Airways
Charterer:	Sabre Airways
Take-off weight:	70.136 Kg
Maximum landing weight:	64.500 Kg
Actual landing weight:	63854 Kg
Fuel remaining:	7.400 Kg
Centre of Gravity:	32 % MAC

1.6.2. Certificate of airworthiness

Type:	Transport Category (Passenger)
Date issued:	29/04/1996
Expiry date:	29/04/1999

1.6.3. Maintenance record.

Total flying hours:	22265
Last 100-hours check:	20/05/1998

1.6.4. Engines.

Manufacturer:	C.F.M.	
Model:	CFM 56-5A3 Turbofan eng.	
Position:	Nº 1	Nº 2
Serial number:	731350	731684
Total flying hours:	20739	16919
Total cycles:	9989	7864

1.6.5. Braking and Anti-Skid System Description

The aircraft was designed with two braking systems; 'Normal' with pressure supplied by the Green hydraulic system, and 'Alternate' with pressure supplied by the Yellow hydraulic system. The Normal system provides 'brake by wire,' Autobrake and Anti-Skid functions via the BSCU (Brake and Steering Control Unit).

In the event that the Normal system is inoperative, Alternate braking should be made available by a spring-biased changeover valve (Automatic Selector Valve), which allows Yellow hydraulic pressure to the Alternate braking system. This is a system whereby braking is achieved via foot pedal master cyliders through a low-pressure auxiliary hydraulic line. Pressure is ported to the Alternate servo valves via a Brake Dual Distribution Valve (BDDV) and a Dual Shuttle Valve, with the anti-skid function being controlled through the BSCU, if still operative. There is one servo valve for braking pressure control on each wheel for the Green system plus another one for the Yellow system. A triple indicator on the central instrument panel in the flight deck shows the Alternate system pressure ported to the left and right wheels, as well as the pressure in the accumulator.

In addition, a Parking Brake is also provided, which operates off the Yellow system, backed up by a Brake Accumulator. Operation of the Parking Brake handle applies unmodulated, reduced to 140 bars, Yellow hydraulic pressure to the brakes by the Parking Brake valve

The full system description as presented in the Flight Crew Operating Manual is shown in Appendix B, with a more detailed braking system schematic presented in Appendix B Figure 1, page 18.

1.6.6. BSCU - Brake & Steering Control Unit.

The BSCU (Brakes & Steering Control Unit) is a computer that controls the Normal braking, Autobrake function, Nose Wheel Steering and Antiskid (on both Normal and Alternate systems). It consists of two physically distinct but functionally identical channels (1 and 2, or A and B) which have independent power sources from No 1 and 2 electrical busses (See Appendix B Figure 2).

The system is controlled by either one of the channels, whichever is powered first at start-up, or No 1 if the computer is reset via the Antiskid and nose wheel steering ON/OFF switch ("A/SKID & N/W STRG") on the flight deck, i.e. the main BSCU switch.

If a fault develops in the channel in control, (i.e. active), the design logic decrees that the passive channel takes over. This becomes a non redundant operation and the active channel cannot relinquish control.

Each of the two channels has a command or control function ("command" or COM) and a monitor function ("monitoring" or MON); the monitor function checks for agreement with the command function output before any output is sent. If the monitor function does not agree with the command function, a 'disagree' condition is logged within the BSCU and also sent to the CFDIU (Centralised Fault Data Interface Unit).

If a disagree or any failure occurs in redundant mode, (i.e. the other channel is still functioning) the system transfers control to the passive channel, which then becomes active and operates in a non redundant mode. If a disagree occurs in a non redundant mode, some or all functions may be lost, the surviving and active channel at the moment of the failure provides the remaining functions.

The Autobrake function controls the level of braking demanded by the pilot by providing a given level of deceleration, for Autobrake 'LO' this is -0.17g. The amount of braking to give the desired level is signalled to the servo valves. The pilot pre-selects the Autobrake level via switches in the cockpit, 'LO', 'MED' or 'MAX'.

Normally, on touchdown the BSCU channel in command will open the Normal Selector Valve, allowing Green pressure to the four servo valves of the Normal system ("Normal Servo Valve"). The level of braking is then controlled by the current applied to the servo valves at each wheel by the BSCU. There are two solenoids in each of the servo valves, one controlled by each of the BSCU channels.

The BSCU performs a functional test at Landing Gear down selection. This firstly opens the Normal selector valve. Although the operation of this valve is not sensed, the BSCU then sends a current to open momentarily each of the Normal servo valves, and monitors the consequent pressure rise. Full release (i.e. brakes off) corresponds to a maximum current value of 38mA. The valves are then closed again, the Normal selector valve closed, and the servo valves fully opened to release the pressure. This test cycle would have occurred on the accident flight, at gear down selection after the failure of both BSCU channels.

1.6.7. BSCU, internal disagreement logic.

The status of the autobrake selector pushbuttons is acquired asynchronously by the command and monitor functions every 20 ms. Having detected the pilot's selection, the command channel then sends a signal to the light in the Autobrake switch via a relay. Therefore it is possible that a short switch operation can be detected by the command function and not by the monitor function (or vice versa), causing a 'disagree' within one channel of the BSCU, or in both channels.

After a six seconds confirmation time, this channel then logs a 'disagree' fault with the BSCU, which is sent to the CFDIU, resulting in a BSCU failure message on the ECAM screen. After four seconds it hands over control to the other channel. The same input can also be detected by the other channel; this also logs a failure message but as it is in a non redundant mode the design logic dictates that it cannot relinquish control. It will be appreciated that in the event of a short button push, the same command/monitor disagree could occur in both channels.

The disagree failure message remains in the channel which is still in control. On the accident flight the Autobrake 'LO' switch was turned off and on again; however this cannot break the disagreement, except when repeating the primary fault – a highly improbable occurrence. Thus the deselection/reselection of the AUTO/BRK LO switch had no effect; the only way to clear and eliminate the fault would have been to reset the BSCU (A/SKID&N/W STRG) OFF-ON switch, i.e. to switch it consecutively off and then on.

On touchdown, four seconds after the spoilers deployment signal, the Autobrake of the BSCU demands to the command function to apply the current to open the normal selector valve. The monitor function senses that the command is making a demand that is inconsistent and at this point the fault takes effect due to the command/monitor disagree. The Normal selector valve never opens, the Autobrake function is lost and the Normal braking system is left inoperative.

This is recorded in the CFDIU as a failure occurring in the Normal servo valves, which is then sent to the ECAM as a "BRAKES AUTO BRK FAULT" warning message. During the landing, phases 8 and 9, until final engine shut down, this failure message is inhibited and it is not displayed to the pilots. However it is recorded in the post flight report (PFR), see section 1.11.3.

1.6.8. Warning and failure messages.

Most of the electronic systems interface with the Centralised Fault Display System (CFDS), the main component of which is the Centralised Fault Data Interface Unit (CFDIU).

Failure messages and ECAM warning messages are recorded by CFDIU. Only ECAM warning messages are displayed to the crew and some are inhibited from display during critical phases of flight.

The data stored in the CFDIU, can be accessed via the Multipurpose Control Display Units on the flight deck pedestal, and are presented in the form of Post Flight or Last Leg Reports. Fault messages with more internal information on the components are also stored and can be accessed by maintenance personnel in order to trouble-shoot problems.

1.7. Meteorological information.

The METAR's at 00.30 hours and 01.00 hours were the following:

Hour:	00.30 h.	01.00 h.
Wind:	010º/05 Kts	020º/04 Kts
Visibility:	CAVOK	CAVOK
Temperature:	+18 ºC	+18 ºC
Dew point:	+14 ºC	+14 ºC
Q.N.H.:	1.016 hPa	1.016 hPa

There were no significant weather phenomena and no significant change was expected.

1.8. Navigation aids.

The aircraft conducted the ILS approach for Runway 24 (actual heading 244º) which was reported to be fully serviceable. The flight crew did not report any abnormalities with the navigation equipment and the approach was conducted normally.

All visual aids for approach and landing were operative and functioned properly.

1.9. Communications.

Communications of the aircraft with the various control centres along the route and Ibiza Tower Control were normal and satisfactory at all times.

1.10. Aerodrome information.

Runway 24 at Ibiza Airport has a Landing Distance Available of 2,800 metres. The runway is 45 metres wide and is equipped with High Intensity Runway Lighting, Centreline Lighting, a High Intensity Approach Lighting System cat. I of 900 metres and Precision Approach Path Indicator System on the left side of the runway, giving a 3° glidepath angle.

The runway has a 60 metre stopway (SWY) at the western end. The overrun area (CWY), of 60 metres by 150 metres, consisted of levelled open terrain. The area behind the SWY-CWY was almost level, slightly sloping to the right down to a drainage trough, and it was covered by tall grass and sparse wild scrub vegetation; then it sloped up at a higher angle and it was here where the aircraft came to a rest. Some 350 metres beyond the end of the runway was the airport boundary concrete and stone wall, which bordered onto a beach and the Mediterranean sea.

1.11. Flight recorders.

1.11.1 Digital Flight Data Recorder (DFDR)

The aircraft was equipped with a Sundstrand Universal Flight Data Recorder (UFDR), model 980-4100-AXUS, with a recording duration of 25 hours using magnetic tape. An initial replay was attempted using the facilities and the standard interface unit connected to the UFDR. Although some data was obtained, the data ended with the aircraft still travelling at a speed of 65 kts and so did not cover the final period of the landing roll. Further attempts were made to replay the recorder, but no further information was obtained.

The unit was then examined in Madrid at the airline workshops. The tape enclosure was opened and the tape found to be damaged such that the unit would not run. The supply and take up reels are driven by a peripheral belt. As found, the peripheral belt was curled over the reel and the tape stack was uneven. The tape path from the supply reel to the take up reel, over the record heads, passes over a number of tape guides. At one of these tape guides, the tape had actually become doubled over causing damage to the tape.

The tape was removed from the recorder and replayed on an 'open reel' system at AAIB in Farnborough, UK. Data covering the period of the landing roll and up to when the aircraft was shutdown was recovered; however due to the tape damage which had occurred during the first attempt to replay the recorder, some areas of data could not be recovered.

The FDR does not run continuously when it is recording. It stores data into one of two volatile memory stores, each holding approximately one second of data. When one memory is full, the data flow is switched to the other store. While data is being fed to this other store, the tape is rewound and the previous second of recorded data is checked. A gap is left on the tape and the data from the first store is written to the tape after said gap, and the first memory is emptied. The whole 'checkstroke' operation takes much less than one second to complete so that once the second store is full, data is switched back to the first store, and the second store is written to the tape using the 'checkstroke' operation again. The procedure is then repeated. When power is lost from the recorder the data held in volatile memory, which has not been recorded on the tape, is lost.

During replay the FDR runs continuously and the most frequently reported failure mode in this condition is tape 'coning', where the flat disk appearance of a normal tape pack is distorted. When this occurs the tape becomes misaligned with the heads and no signal is obtained from the tape. In this case the tape probably 'coned' during the initial replay by standard means, and continuing to run the recorder caused the damage seen in the tape assembly (see Appendix C).

This FDR had been fitted to the aircraft on 20 May 1998, the day prior to the accident. A Solid State storage unit had been removed for a routine readout. No faults were found with the FDR when it was sent for investigation after the accident, and the recovery of all the data up to the loss of electrical power indicates that the recorder had been serviceable.

The recording on FDR stopped 63 seconds after touchdown as the engines were shutdown and electrical power was lost.

Data from the initial readout and the final 'open reel' replay were combined to produce the final listing of the last 70 seconds of data.

The initial Autobrake LO selection was made at 23.55 UTC (52 minutes and 28 seconds before touchdown), during the cruise at an altitude of 33,000 ft. This parameter is sampled and recorded every 4 seconds by the FDR; the selection remained on for 8 samples (32 seconds), it was then deselected for a further 24 samples (1 minute 36 seconds) before being reselected where it remained for the rest of the flight.

Appendix D Figure 1 shows the final minute of FDR data covering the approach and landing from 20 ft AGL to the end. Relevant comments from the CVR are included. The aircraft touched down at an airspeed of 132 kts CAS, at a distance calculated to be 2000m from the end of the paved surface. Figure 2 shows the calculated distance and Figure 3 shows the FDR data and relevant CVR comments plotted against the distance form touchdown.

The Autobrake fault discrete indicated a fault condition as soon as the aircraft touched down. The ground spoilers and reverse thrust were deployed less than one second after touchdown. The initial deceleration was –0.18g, three seconds after touchdown. Around seven seconds after touchdown the brake pedal angle position indicated that there was a pilot demand for manual braking.

Around 20 seconds after touchdown the commander said ‘bit more braking I should think’. Seven seconds later the first officer said ‘I haven’t got any brakes’. The maximum brake pedal angle was demanded around 20 seconds after touchdown by which time the longitudinal deceleration had reduced to –0.09g.

Around 30 seconds after touchdown reverse thrust was de-selected and then reselected.

The full braking demand continued until the aircraft left the runway 42 seconds after touchdown. The aircraft left the runway with an airspeed of 50 kts, and a groundspeed of 55 kts. The heading was 246° and the aircraft continued to turn to the right onto a final heading of 350°. The high brake pedal angle demand was maintained on the right brake, but reduced on the left brake during the right turn.

The calculated total distance from touchdown to the aircraft stopping point was 2250 m. As the aircraft came to rest 250 m. beyond the end of the paved surface, a peak longitudinal deceleration of –1g was recorded.

1.11.2. Cockpit Voice Recorder (CVR).

The aircraft was equipped with a Fairchild model A100 re-cycling CVR which records the latest 30 minutes of audio information on four tracks. The recording covered the period from the top of descent to landing at Ibiza and therefore includes the approach. The recording stopped as the aircraft came to rest and the crew ordered the evacuation.

Because of the limited duration of the recording, the crew actions at the time of the initial Autobrake LO selection, which occurred around 52 minutes before touchdown, were not available.

1.11.3. Post Flight Report (PFR)

In the first hours after the event, attempts were made on board the aircraft to obtain the Post Flight Report (PFR). However, damage to the nose landing gear had caused the CFDIU effectively to become locked in 'flight' mode. Thus it was necessary for the unit to be sent to the aircraft manufacturer to download the information. The following ECAM Warning messages were recorded, giving the time the message was logged, the flight phase and an ATA reference.

GMT	PH	ATA
2355	06	32-00BRAKES BSCU CH 2 FAULT (2)
0049	08	32-00BRAKES AUTO BRK FAULT

NOTE: Flight phases 6 and 8 are respectively the cruise and that portion of the landing phase between touchdown and 80 kts.

The first ECAM warning message displayed to the crew related to the failure of the No 2 Channel of the BSCU following the Autobrake 'LO' selection. The second message was recorded as the aircraft touched down at 00.49 h. and the Normal braking system became unavailable. However, this was inhibited from display during the landing phase.

The following failure messages were recorded by the CFDIUs:

GMT	ATA		SOURCE
2355	32-42-34	BSCU	BSCU B
2355	32-42-34	BSCU	BSCU A
0049	32-42-48	BRK NORM SERVOVALVE 15GG	BSCU A
0049	32-42-48	BRK NORM SERVOVALVE 17GG	BSCU A

The first message relates to the disagree failure message on Channel 2 (B) and was transmitted to the ECAM as shown above. The second message shows the disagree failure was present in Channel 1 (A) as well. The second message was not displayed on the ECAM; it was indicated only by the "(2)" data item in the ECAM warning messages on the PFR , this indicated that the failure affected both channels. The final two messages, which include servo valve reference numbers, relate to the failure of the BSCU as it attempted to prepare to apply the desired Autobrake after touchdown.

1.12. Wreckage and impact information.

An inspection of the site, including the second half of the runway, showed that the aircraft had made two swerving turns before running off the end of the runway. The path of the aircraft as it ran off the end could be seen clearly by the marks left by the tyres of all the landing gear wheels. The initial swerve to the right, on the runway, could be detected by tracing the marks left by the tyres back to their origin. Further back-tracking of the runway from this point did not reveal any evidence of tyre marks resulting from braking action leading into the marks of this first swerve.

The aircraft had deviated first to the right (see Appendix A), with the right main gear coming within 2 metres of the runway edge. It had then run diagonally across the runway after swinging left and leaving the runway extension considerably to the left of the centreline and on a heading slightly to the right of the runway direction. The aircraft then continued to turn to the right as it ran across the grass at the end of the runway, breaking several of the airfield lights at runway 06 end during its progress. It came to rest when it struck a low earth bank about 300 metres after leaving the runway, 120 meters to the right of the extended runway centreline and 250 meters from the end of the runway end on such centreline. The first impact was with the nose-leg, which collapsed aft and then fractured just above the axle, and the aircraft was finally halted when the engine intakes struck the bank. There was no evidence of any braking action during the passage of the aircraft across the grass.

During the swerving portions of the tyre marks, the path of the nose-wheels was always closer to the path of the main-wheel on the inside of the curve. This indicated that the aircraft was skidding laterally at those points. Examination of the tread surface on all tyres showed evidence of severe abrasion marks in a lateral direction, consistent with sideways slipping of a freely rolling tyre.

As a result of these first examinations it appeared that there was no evidence of any braking action occurring at any time during the landing roll and that the technical investigation focussed on the reason for this.

1.13. Medical and pathological information.

There were no medical factors involved in this accident. Many passengers experienced minor evacuation injuries from contact with the slides or from contact with the coarse vegetation surrounding the aircraft's final stopping location.

1.14. Fire.

Any side of the aircraft or engines did not catch fire. Although the aircraft was carrying some 7.4 tonnes of fuel, there was no significant fuel leakage and no fire ensued.

1.15. Survival.

There were no failures of any of the crew or passenger seats on the aircraft and no disruption of the cabin or flight deck of the aircraft.

From reports by cabin crew members and some of the passengers, it was apparent that the aircraft's emergency lighting system did not operate initially, but come on a short time later. Subsequently, no fault could be found with the operating system.

Shortly after the aircraft came to a stop, there was apparently smoke or dust visible in the cabin. Having already sensed the swerving towards the end of the landing roll, and the rough ride over the terrain in the overrun area, the cabin crew called to the passengers to adopt the brace position. When the aircraft stopped, the cabin crew self-initiated their evacuation procedure at the front initially, followed by the rear cabin. According to cabin crew reports, all of the passenger and service doors opened normally and each of the slides inflated automatically and normally.

The cabin crew reported that one of the rear cabin crew members had tried to make her way up the cabin towards the overwing exit location, but by that time most of the passengers were standing in the aisle and further progress was not possible. She attempted to call to the passengers by the overwing exits to open them, but they did not do so, preferring to join the flow of passengers to the main door slides. Some passengers also attempted to retrieve hand luggage from the overhead lockers prior to evacuation.

It was noted that all four of the cover plates for the operating release handles of the overwing escape hatches had been removed by the passengers during the evacuation, but none of the hatches had actually been removed.

On leaving the aircraft, the cabin crew attempted to round up the passengers into a group to await assistance from the airport emergency services. Some passengers were abusive and unruly during this process.

The airport fire services were apparently on scene within five minutes of the accident. One female passenger suffered an asthma attack and required medical attention. The cabin crew commented that there was a significant delay before the ambulance arrived at the scene.

1.16. Tests and research.

1.16.1. Tests with the complete aircraft.

Following temporary repairs the aircraft was flown on 17 June, with the landing gear extended and at a maximum altitude of 9,000 ft, from Ibiza to Toulouse. Except the brakes, the braking system components were not changed for this flight.

During the flight, the crew attempted to reproduce the Autobrake defect that occurred prior to the accident. Numerous selections were made on the LO, MED and MAX push-buttons, without result.

A successful Autobrake 'LO' landing was carried out, although the push-button did not illuminate. During the landing roll, the DECEL caption also failed to illuminate, and an ECAM message, to the effect that BSCU Channel 2 was inoperative, did belatedly appear. LO Autobrake effectively selects a longitudinal deceleration of 0.17g, and the DECEL light illuminates at 80% of this value. Later evaluation of the recorded data for this flight showed that the peak retardation was 0.16g; thus the light should have been on.

On the ground, the aircraft was prepared for a series of simulated flights during which the Alternate brake system was functioned during each "landing". This involved interposing a breakout box between the BSCU and the aircraft such that the BSCU could be fed with signals which simulated the inputs from, for example, the inertial reference system (giving groundspeed), main landing gear wheel tacho-generators (giving wheel speed), as well as discretes such as ground spoiler deployment. In addition the LO Autobrake button-push was simulated by a pulse of sufficiently short duration to precipitate the command/monitor disagree on both BSCU channels, and which produced the 'Autobrake fail' condition at "touchdown" that occurred on the accident flight. Ground power units were used to pressurise the

Green (Normal brakes) and Yellow (Alternate brakes) hydraulic systems.

During each simulated landing roll, an operator on the flight deck applied the brake pedals which, given the BSCU fault, functioned the Alternate brakes via the Yellow hydraulic system. All parameters were recorded, such that it was possible to monitor the hydraulic pressure at the brakes, together with pedal deflection, as well as the function test of the Normal system that was conducted by the BSCU at each simulated landing gear extension. The test procedure was later modified to include the setting of the park brake at the end of each simulation, which functioned the park brake valve and the operated valve, the integrity of which is fundamental to the operation of the Alternate brake system.

None of these tests showed any abnormality with Alternate brake operation, and so they were repeated with dry ice packed around the brake system hydraulic components in the right hand landing gear bay. This time the accident flight condition was reproduced in that there was no brake pressure in response to brake pedal deflection. Additional pressure transducers that had been installed in the hydraulic system showed that the automatic selector, the Park Brake valve and the operated valve had been functioning as expected, and that Yellow system pressure was available to the BDDV. However no BDDV output pressure was apparent, which thus indicated a problem with this component.

The tests were repeated in order to demonstrate the consistency of the failure condition, and it was found that after the BDDV had been cooled to -40°C and the ice pack removed, then brake function was not recovered until the temperature had risen to an indicated +15°C. However, it must be appreciated that these temperature values cannot be regarded as accurate, as measurement was by means of a probe attached to the valve body, which was therefore not capable of assessing the internal temperature.

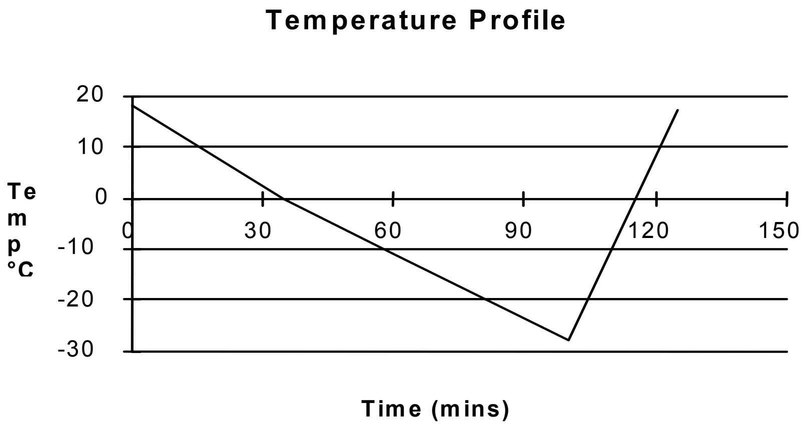
The operator on the flight deck reported that during the failure condition, the brake pedals required a higher force than usual to deflect them.

It was concluded that the most probable explanation for the BDDV's behaviour was water trapped inside which turned to ice at sub-zero temperatures, thus jamming the internal mechanism. It was then decided to conduct additional investigations at Messier-Bugatti, the valve's manufacturers. Accordingly, the BDDV was removed from the aircraft and hand-carried to the manufacturer's facility at Velizy, near Paris.

1.16.2. Tests on the BDDV.

The BDDV was tested in Messier-Bugatti's environmental test chamber in which the temperature could be controlled. The valve was supplied with hydraulic fluid from an external reservoir, the temperature of which was also controllable. Left and right brake pedal input pressures were supplied from two master cylinders. The BDDV input and output pressures were monitored and recorded. Before installation on the test rig, hydraulic fluid samples were taken from the valve ports and attaching pipelines. At this point it was observed that a bead of sealant was missing from the join between the main body of the valve and a cover at its base. However, there was a residue that suggested that sealant had been present at some stage. The reason for the loss of the sealant was not apparent, but was most probably associated with smooth surfaces of the valve and cover providing an inadequate key for the sealant.

The initial test roughly followed the total air temperature profile for the accident flight, as derived from the FDR. Thus the valve was cooled at a near-constant rate to the lowest value of -28°C before being warmed up again to +17°C, as shown below:



The BDDV function was tested after one hour, at which point the temperature was -11°C, with the hydraulic fluid temperature at -3°C. A satisfactory pressure output was obtained in response to brake pedal input. However, when the test was repeated after 1 hr 25 min elapsed time, with the test chamber and fluid temperatures at -20°C and -12°C respectively, no output was obtained, thus reproducing the failure condition. This condition persisted at the lowest temperature of -28°C. The ensuing warming-up process was intended to simulate the descent and landing on the accident flight. After reaching +17°C the fluid reservoir temperature was still at -16.8°C, although its temperature at the input to the BDDV was +12.9°C. The left and right brake functions were tested in turn by applying the maximum input pressure of 12 bar, and maintaining it for one minute. No brake output pressure was obtained on either side. After waiting an additional minute, the tests were repeated, and it was found that normal operation had been restored.

It was then decided to find the lowest temperature at which the BDDV ceased to function. Following a satisfactory function test at ambient conditions, the chamber was cooled to -5°C and stabilised for 35 minutes, by which time the fluid input temperature was still at +4.5°C. The left and right inputs were applied at half the maximum pressure, ie 6 bar, which resulted in brake output pressure. It was noted that a small container of water, which had been placed in the chamber, was not completely frozen at this stage. The act of functioning the BDDV introduced colder fluid from the reservoir into the valve body, which would not be representative of the aircraft installation, where the Alternate brake components are essentially in a stagnant part of the hydraulic system, and where generally warmer fluid would be introduced as a result of brake operation. After an additional 30 minutes at -5°C, with the fluid input temperature close to 0°C, the valve still operated normally. The chamber was then cooled to -10°C and maintained at this value for 30 minutes before testing the BDDV once more. This time there was no output, ie the valve was in the failed condition.

After the chamber had been force-warmed to ambient temperature, the BDDV was subjected to a further test to confirm that it was fully functional again, before being removed from the test rig. The cup-shaped cover at the base of the valve body was removed and found to contain a quantity of fluid. This consisted of 30 ml of dirty water and 3.5 ml of what appeared to be a mixture of hydraulic fluid and grease. This was later analysed by the Fuels and Lubricants laboratories at DERA, Pyestock, United Kingdom, along with the samples of hydraulic fluid taken from the BDDV prior to its installation in the environmental test rig.

The quantity of water/grease was sufficient to fill the cup to within 25 mm from its brim. The lowest part of the rocker assembly extended into the cup by 29 mm. It was thus clear that the rocker assembly would have been immersed in the water to the extent that when it had frozen it could not be moved under the action of brake pedal input pressure.

The moving parts of the valve had been assembled with silicone grease and it was apparent that emulsification had occurred as result of contact with the water. However, there was no visible corrosion that may have impeded the operation of the valve. As a final check, the BDDV was reinstalled, with its cover, in the test chamber and cooled to

-20°C over approximately 30 minutes. It was then functioned after a further 35 minutes, with no problems.

The BDDV was later subjected to a ‘production test’, where brake output pressure was assessed against pedal input pressure. This confirmed that the valve parameters met the normal production requirements.

1.16.3. <u>Preliminary actions taken by the Manufacturer.</u>

Following the discovery of the water in the BDDV, and the BSCU internal disagree condition highlighted by this event, Airbus Industrie issued an All Operators Telex (AOT) No 32-19 dated 07 July 1998 and an accompanying Flight Operations Telex (FOT). The AOT was mandated by four Airworthiness Directives (AD), ref. 34, 35, 36 and 37/98 issued by Certification Authority, on 8 July 1998.

The AOT applied to all Airbus types as the same components are used in the Alternate brake system for both the narrow and wide-body aircraft, although in the latter, the BDDV is located close to the centreline, ie further away from the fuselage skin.

The AOT called for a weekly check (not to exceed 9 days) of the Alternate brake system conducted at the end of the cruise phase. This was achieved by selecting the BSCU Antiskid & Nose Wheel Steering switch OFF, operating the brake pedals and checking the pressure on the triple indicator. The absence of pressure could indicate a frozen BDDV. The failure cases were notified to Airbus Industrie and were as follows:

A319/320/321 fleet: 40 out of 854 aircraft in service.
A310: one case out of 161 aircraft
A300/A300-600, A330 and A340: no cases.

The single case of BDDV failure in the A310 was considered by Airbus to be an 'isolated one', with the results otherwise confirming that the relatively exposed location of the component in the narrowbody aircraft rendered them more vulnerable to contamination. A later revision of the AOT reduced the check frequency to 500 flying hours.

The AOT, which required no maintenance task, was intended to be a temporary solution pending a design fix to the BDDV. Reference was made to a forthcoming Service Bulletin (No. A320-32-1200) which would address this issue.

The AOT also referred to four Flight Operation Telexes (FOTs), Nos. 999.0059; .0060; .0061; and .0062, one for each of the fleets, setting forth an in-flight checking procedure of the Alternate braking system and the condition of the BDDV, and the Operational Recommendation for the event of landing brakes failure. The Recommendation added, in connection with the Emergency Procedure set forth for this case, the switching OFF of the BSCU A/Skid & N/W Strg. switch after releasing the brake pedals, applying brake pressure limited to about 1,000 psi, and as a last resort, if the brakes are still unavailable, using the Parking Brake with short and successive applications.

The FOT 999.0059, covered later by the Operations Engineering Bulletin (OEB) nº 137/1 issued in September 98 applicable to the A-319/A-320/A-321 fleet includes an additional Operational Recommendation to avoid the "disagreement" fault in the BSCU when selecting the appropriate Autobrake mode (LO, MED or MAX). The Recommendation specifies that when selecting the Autobrake mode, the push-button or switch should be firmly pressed for at least one second in order to ensure the proper operation of the system. If, in spite of the foregoing procedure, the fault message "BRAKES BSCU CH 1(2) FAULT" appears in the ECAM display, without the other fault message, ie "BRAKES AUTO BRK FAULT", then reset the BSCU with the A/SKID & N/W STG switch and when the landing gear is still retracted.

The AOT also made a declaration of intent to include in the BSCU software Standard 8 (planned for Certification in the beginning of 1999) the appropriate modifications in order to permanently avoid the "disagreement" failure in the BSCU when selecting the appropriate Autobrake mode.

1.16.4. Cold soak tests.

Airbus Industrie conducted a flight test on an A320 aircraft in which two temperature sensors were attached to the BDDV, one on the valve body and the other on the cover. A test flight was also conducted on an A300-600. Once again, two sensors were used, one being attached to the valve cover, but with the other measuring the ambient air temperature 10 cm from the valve. Plots of the two test flights are appended (Appendix E, Figures 3 and 4).

It can be seen that on the A320 test, the temperature before take-off was 30° C. After take-off, the temperature reduced at approximately 0.6° C per minute, with 0° being reached after 50 minutes. The lowest temperature was –8° C, when the total air temperature (TAT) was –22° C. During the cooling process the sensor on the valve cover consistently registered 2° C below that of the one on the valve body, possibly because of the higher thermal inertia of the latter. The TAT then rose to –10° C and the valve cover temperature stabilised at –6 °C. For the flight profile flown, the valve temperature rose above –0 °C, 10 minutes after leaving flight level 330 with –10 ºC of TAT. After landing, the Antiskid system was switched off and Alternate brake pressure was confirmed.

In the A300 test the TAT reduced rapidly to a low of –30° C, with the BDDV valve cover temperature reducing at around 0.9° C per minute to a minimum value of –14° C. The aircraft then flew at lower altitudes than for the A320 test, so that the valve temperature was above zero for one and a half hours before landing.

1.16.5. Analysis of the fluid found inside BDDV cover

The DERA Fuels and Lubricants laboratories separated the water based contaminant fluid found within the BDDV into three phases; water, oil and a solid sludge:

a) The water contained a significant concentration of detergent (>0.25%), indicating contamination by a cleaning fluid or solution. .

b) The oil was essentially phosphate ester hydraulic fluid with small amounts of trichloroethylene and high molecular mass hydrocarbons.

c) The sludge contained a number of elements, the most predominant being silicon, indicating the presence of a silicone based grease.

Analysis of the hydraulic fluid samples taken from the BDDV valve ports showed consistency with normal phosphate ester type hydraulic fluid, with traces of pentane and 3-methyl pentane, possibly from solvent cleaning. All the samples were clear and bright, but contained either suspended particles or fine sediment.

The owner and operator provided details of the proprietary cleaning fluids used in aircraft washes. Samples of these were mixed with water at the dilutions required by the manufacturers and tested by DERA in order to determine the freezing points. It was found that these varied between 0 °C and –0.75 °C. It is understood that the usual concentration for cleaning was one part detergent to 20 parts water.

1.16.6. BDDV history.

The BDDV was manufactured in August 1992 as Part Number A25434004-3A, with Serial Number 1255. It was fitted as original equipment to a Monarch Airlines A320, G-OZBA in March 1994. It was removed on 28 November 1996 and returned to Messier-Bugatti as part of a rolling modification programme on the component. This involved the embodiment of three Service Bulletins (SBs), Nos 580-32-3091, -3099 and -3103. These respectively changed the valves' input/output characteristics, checked a chamfer on one of the internal valve lands (which eliminated a potential problem with uncommanded application of brake pressure) and deleted the automatic bleeding facility. In fact SB 580-32-3099 was found already to have been embodied. The unit was released back to Monarch under a new Part Number, A25434006–2A, although the original serial number was retained. The accompanying release paperwork included a JAA Form 1, which was dated 24 December 1996.

Leisure International obtained the BDDV from Monarch and installed it on G-UKLL on 5 February 1997, the unit it replaced being returned to Messier-Bugatti for the same modifications to be embodied. The BDDV remained on the aircraft until the accident. There was no record of any further maintenance being carried out on the unit.

1.16.7. BSCU history and tests.

The BSCU, Part No C20216332292C Amendment A, Serial No 329, was fitted to the aircraft in February 1997 and had achieved 4,719 hours at the time of the accident. The unit was received from Messier-Bugatti with software Standard 7 installed.

The BSCU was tested on an automatic test facility at Aerospatiale, Toulouse. A failure was detected and subsequently the unit was disassembled to its individual circuit boards.

During this process it was observed that some of the components close to the ventilation holes in the casing were covered with what appeared to be carbon deposits. It was considered that this could have originated from the exhaust gases of ground power units parked close to the avionics bay air inlet. This did not appear to have affected the functionality of the boards however.

The only confirmed defect was a failed relay which controlled the LO Autobrake ON and DECEL lights on the switch panel. This accorded with the report of the ferry flight made from Ibiza to Toulouse on 17 June, following its temporary repair.

No other failures were detected and the non-volatile memory contained the failure messages relating to the accident flight and the subsequent testing.

1.16.8. Brake Control Panel Tests.

The Brake control panel, located in the cockpit, was tested on the appropriate test rig at Aerospatiale's Toulouse facility. It was found that one of the two bulbs in the MED Autobrake ON push switch had blown. Otherwise the unit functioned satisfactorily.

The contacts of each of the Autobrake switches are maintained at 14 volts; pressing the switch grounds the contact, thus giving zero volts. This is detected by the two "command" and "monitor" functions within the BSCU, which enter the appropriate MAX, MED or LO Autobrake selection.

The switch panel was subsequently tested on Airbus Industrie's engineering test rig (the "iron bird"), with the switch function being visualised on an oscilloscope. This showed that when the switch was pressed, the voltage drop was virtually instantaneous after some "noise" lasting approximately 2 milliseconds. Thus the period at zero volts was effectively the same duration as the button-push less 2 milliseconds.

The use of the oscilloscope allowed a further opportunity to provoke the COM/MON channels disagree within the test rig's BSCU, as each channel's Autobrake ON/OFF state was represented by a different voltage line. Usually, and according to the expected functioning, both channels would change simultaneously on pressing the Autobrake LO switch; however, if the push was less than approximately 50 milliseconds and more than 20 milliseconds (which was quite difficult to achieve in practice), only one of the COM/MON functions would change state, and the other would not. The oscilloscope charts with the voltages for the COM/MON functions plotted to Auto/brk LO button push are shown in Appendix F.

1.16.9. <u>Relevant aircraft history.</u>

The operator supplied a record of braking system defects for the period 1 January to 20 May 1998. These were few in number and were mainly concerned with brake pads being worn to limits, or high brake temperatures being noted after landing. There were no recorded problems with brake functioning or operation.

A Major Check "C" was carried out on the aircraft 14.5 flying hours before the accident. According to the Operator, the only item remotely relevant to the accident was the replacement of the No 2 brake assembly.

In view of the fact that detergent was found within the BDDV, the recent history of aircraft washes, which was carried out by a contractor, was obtained. This was as follows:

19 May 1997	Belly wash by hand
26 May 1997	Belly wash by hand
9 June 1997	Full Wash

16 June 1997	Belly Wash
14 July 1997	Belly Wash
28 July 1997	Full Belly Wash
6 August 1997	Spot Wash
13 November 1997	Full Wash

The contractor ceased the washing services after November 1997, following which the washing history is incomplete. However, the contractor´s procedures provided for hand washing of the landing gear indicated that the washes were conducted with the wheel well doors closed, thereby shielding the hydraulic system components, including the BDDV, from direct impingement from hose pipes.

1.17. Organisational and management information.

Not applicable.

1.18. Additional information.

1.18.1. Subsequent Actions by the Manufacturer on the BDDV

On 5 September 1998, Airbus Industrie issued Service Bulletin No. A320-32-1200, which advised all operators of A319, A320 and A321 aircraft of the issue of Messier-Bugatti Service Bulletin No. A25434-32-3172. This proposed the modification of the BDDV by drilling a 6 mm diameter drain hole in the bottom side of the cover and lubricating all parts of the rocker arm mechanism inside the cover. This was intended to prevent the accumulation of large quantities of water inside the cover, and to prevent jamming of the rocker arm mechanism under freezing conditions. The information page on the Bulletin concludes as follows:

Accomplishment of this Service Bulletin is recommended in the event of failure of the weekly in-flight check of the functioning of the Alternate braking system, required by Airworthiness Directive (Consigne de Navigabilite) ref. 34/98, No. 98-262-120(B).

Following the accomplishment of the Bulletin, the weekly check on the Alternate braking system was no longer required.

The Bulletin acknowledged that drilling a hole in the BDDV cover could allow the ingress of water, dust and other contaminants into the valve components, and that this was therefore also and only an interim measure. The final solution was by way of Service Bulletin No. A320-32-1203, which introduced a new design of seal between the cover and the body of the valve and a clear plastic drain and stopper from the BDDV cover. This was issued by Airbus on 4 June 1999 and make mandatory by AD – 2000-258-146 (B) although it was initially installed on new-build aircraft.

1.18.2. Subsequent Actions by Manufactures on the BSCU.

The BSCU has had a number of software upgrades, with Standard 7 being installed in the unit fitted to the aircraft at the time of the accident. Software Standard 8 was introduced including a revision to address the problem caused by short button-pushes of the Autobrake. However as a result of in service evaluation, Standard 8 was supersedes by Standard 9, which became available from beginning of June 2001, reference OIT 999.0078/01/BB as a recommended customer option upgrade.

1.19. Investigation techniques.

The first phase of the investigation was conducted at the accident site, there being no need to move the aircraft since it did not interfere with the Airport operations and this offered the added facilities of being in an enclosed area, easily accessible for investigators and with the airport facilities nearby. However, neither in the Airport nor in the Island there were hangars or other aeronautical facilities in which to conduct subsequent tests on the aircraft systems.

Some days later, the aircraft was moved to the apron beside the terminal buildings, where the basic repair of hydraulic leaks was continued in order to be able to conduct tests on the Normal and Alternate Braking systems. The successful completion of these tests faced innumerable limitations as regards equipment and facilities.

When the possible factors that had caused the event had been found to be confined to the hydraulic braking system and its electric/electronic control — although with the specific elements or units that caused the malfunction still not identified — it became apparent that this system, complete and fitted to the aircraft, required a comprehensive test, since in the A-320 aircraft family there is a very close relationship among various electronic-computing pieces of equipment and the electro-hydraulic mechanisms. For this reason, the testing of individual units or mechanisms was thought to be less likely to reveal possible discrepancies or abnormalities.

The aircraft had sustained relatively little damage and it could be recovered for flying after a short time. For these and the above referred reasons, it was suggested and accepted to ferry it after making the essential repairs to the Manufacturer's facilities in Toulouse, where the best possible infrastructure for conducting the necessary tests was present.

In spite of the difficulties that the transportation of the aircraft involved, this was successfully completed within 30 days from the accident. During the ferry flight, taking care to cause the least possible interference with the aircraft systems in order to avoid to masking or deleting the faults that caused the accident, the general parameters were recorded and some functional tests of the braking system were conducted in order to go ahead with the detection of the causes of the accident.

The availability at the manufacturer's premises of a nearly complete aircraft with the same systems and components as those fitted to the aircraft at the moment of the event, greatly and effectively helped to quickly clarify the causes, since there were provided a complete braking system fitted to aircraft itself and the resources required to conduct the tests and to obtain the maximum information thereof.

2. ANALYSIS.

2.1. Behaviour of the aircraft.

In this accident two independent failures occurred, within Normal and Alternate braking systems. The initial failure occurred at autobrake selection, the other failure was a dormant condition within the BDDV.

2.1.1. Loss of Normal braking system.

The initial failure took place during the cruise phase (phase 06) at 23.55 hours, when the handling pilot selected AUTO/BRK LO. This quick button push and the subsequent input to the BSCU caused an internal logic "disagreement" between the monitor function and the command function in both channels simultaneously, ie in the active one (Channel 2) and in the passive one (Channel 1). One of the functions, either the monitor function or the command function, registered the button push, but the other one did not.

This disagreement prompted an ECAM warning message, BRAKES BSCU CH 2 FAULT, which required no action by the crew in accordance with the Aircraft´s Flight Crew Operating Manual section 3.02.32 (FCOM). However, 35 seconds after AUTO/BRK LO selection, the pilot deselected it in an attempt to correct the malfunction and selected it again 1m35s later.

The Brakes and Steering Control Unit (BSCU) was left with a malfunction in both channels. Channel 2, the currently active channel, transferred control to Channel 1, which remained as active channel in spite of having a fault. This malfunction resulted in the Autobrake fault and the failure of the Normal braking system.

During landing, as it was to be expected after the occurrence of the failure, the malfunction became apparent in the autobrake function and the Normal braking system. However, it did not affect the nose wheel steering, since this was operative as evidenced by the swerves performed at the end of the path followed by the aircraft on the runway.

2.1.2. Loss of Alternate braking system

The second failure was detected during the landing roll when the handling pilot applied the brake pedals, at some seconds after 00.49 hours. At this moment, on application of the brake pedals, the Alternate braking system should have been available. However, the BDDV failed to function because of the presence of a frozen aqueous solution in its lower cover that caused the internal rocker assembly to be locked.

This second failure completely prevented the brake pedal application from sending pressure to the main gear wheels through the Alternate servo valves via the Yellow hydraulic system. During the landing roll the brakes did not receive pressure from the Green (Normal braking system) or the Yelow (Alternate braking system) hydraulic circuits, in spite of there being hydraulic pressure available on both braking systems.

The only braking system working after these two failures was the Parking Brake, which uses unmodulated hydraulic pressure from the Yelow hydraulic circuit. In this case the Parking Brake was not used by the crew.

2.1.3. Detailed analysis of failures.

Post accident tests indicated that no significant failures had occurred in the BSCU, with the result that attention was focused on the consequences of the “short button-push” during Autobrake selection. The independent processors within the command and monitor areas of each BSCU channels spend only limited time, around 20 milliseconds, “looking” for a change of state of the Autobrake push-button signal wires, ie a voltage drop from 14v to 0v.

A short button-push of around 20 to 50 milliseconds can result in either the command or the monitor function not registering the 0v signal, thus producing the command/monitor disagreement. It is probable that such a condition had occurred previously on Airbus aircraft, since Airbus Industrie were aware of the possibility and there are precedents of similar faults concerning at least the use of the AUTO/BRK MAX button, although this was probably the first known occasion that the disagreement had occurred simultaneously on both the active and the passive channels.

The design logic decreed that, following the failure of a BSCU channel, the remaining one could not quit. However the command/monitor disagree condition still existed in the channel that was now active, thus as soon as the brake servo valves started to open (as commanded by the command function), the monitor failed the channel.

Since this was always going to happen, it could be argued that the condition was detectable and therefore capable of being transmitted to the crew, via an ECAM message, well before landing. Such a warning would at least have permitted the option of resetting the BSCU, which would have rectified the problem in this case. Thus the logic fault not only failed the Autobrake facility, but also failed to allow manual ‘brake by wire’ using the normal, and otherwise perfectly serviceable, hydraulic system. There must be a concern that other circumstances could conspire to cause the software to similarly hazard the aircraft by closing down a serviceable system.

In this case, computer control of the brakes ended when the BSCU closed the normal selector valve, thus causing the spring-loaded automatic selector valve to bring in the alternate braking system. The jammed mechanism within the BDDV, caused by ice, represented a dormant failure condition of a component that is maintained “on condition”, ie does not receive regular, periodic inspections.

The presence of detergent in the water found within the BDDV cover indicated that aircraft washes (probably using hose pipes) were the cause. The water from the other failed BDDVs found as a result of the weekly checks was not analysed; thus the link to aircraft washes was not confirmed in these cases. Indeed, it seems unlikely that it would have been a factor in every case. Nevertheless, a high pressure hose would seem the most likely means to introduce water via the junction between the valve body and the cover.

There is also a possibility that a contribution could be made by rain impinging on the BDDV during the short period the belly door is open each time the landing gear is extended or retracted, or even while rolling on the runway with the doors closed, since water can filter in through the slots between the doors when closed. In this way, detergent residues dried on the exterior fuselage or exposed landing gear could have become liquid again when combined with water spray and thus found their way into the BDDV through the defective valve sealing.

The sealant bead between the valve body and cover probably contributed little in the way of excluding water due to the lack of adhesion between the sealant and the smooth external finish on the surfaces. The internal components of the valve are machined to very close tolerances and the use of sealant reflects the manufacturer’s desire to exclude the risk of any contamination through any gaps between the valve body and cover. The interim Service Bulletin counterproductively involved increased risk of contamination by drilling a 6 mm diameter hole. The final solution hopefully has eliminated this risk.

2.2. Actions by the Crew.

2.2.1. Flight Deck Crew Procedures.

Regarding Autobrake Low selection, there was no reference in the FCOM to a specific method of pressing the Autobrake selector button. The crew member performing this selection may make a quick or a slow button-push, and even the duration of the button-push might in some cases be affected by a vibration or movement of the aircraft. A minimum time of 1 second has been introduced by Temporary change notice to the FCOM, make definitively by OEB nº 137/1 of September 98.

The only reference in the ATA 32, Landing Gear, warnings and precautions section of the FCOM Vol 3 Section 2 regarding BSCU CH 1(2) FAULT indicated that such fault message was for crew awareness. No other specific action was recommended, even though switching the BSCU-A/SKID&N/W STRG switch OFF then ON again would have reset the system logic and cleared the fault condition.

Regarding BSCU resetting (switching OFF and then ON the A/SKID & N/W STRG selector-switch), the information appearing in the FCOM, Volume 3, Section 4, Supplementary Techniques, indicates that in the case of difficulties with the brakes and/or steering the BSCU may be reset, in particular in the cases in which any of the following ECAM warnings is displayed:

WHEEL N.W.STEER FAULT
BRAKES AUTO BRAKE FAULT
BRAKES BSCU CH 1 (2) FAULT

On the ground, reset with the aircraft stopped; in flight, reset with the landing gear retracted; and no resetting is to be made in the event of an AUTO BRAKE FAULT in order to avoid clearing an actual tachometer fault. Also, there is an explanatory Note reminding that BSCU resetting on the ground with the aircraft moving is not recommended, although it may be attempted if both channels, 1 and 2, are lost and the crew cannot keep the aircraft within the runway and provided that care is taken to ensure that during resetting the nose wheel is at neutral position, the rudder pedals are at neutral, and the brake pedals are released.

The crew were not aware of the presence, in the Supplementary Techniques Section 4 of the FCOM Volume 3, landing gear, LOSS OF BRAKING: In a case of extreme emergency, and only if the pedals are ineffective, with the BSCU switch in OFF, the aircraft may be stopped with the Parking Brake (full pressure application will occur); ie the possibility of using the parking brake in the event of extreme emergency.

There was no reference whatsoever, in the FCOM Vol 3 Section 2 Abnormal and Emergency Procedures section regarding the crew action to be taken in the event of a loss of braking, as was experienced on this occasion. This action is now a 'Memory Recall' item and has been included in the Abnormal & Emergency Procedures Section.

The crew of G-UKLL had not been trained on the emergency use of the Parking Brake switch as an alternative method of stopping the aircraft and as last resort after loss of both the Normal and Alternative systems nor has this use been explained to them during their training courses. As the information gathered reveals, the standard training courses given before the event for training of pilots of the Airbus-A320 family apparently did not mention or include training on the use of the Parking Brake as a last-resort Emergency brake, although some other A320 pilots did have knowledge of it.

Regarding the use of the parking brake, to use it with the aircraft in motion is not intuitive and crews know that its use causes a highly intense braking that can only be modulated by rapidly and successively switching the lever from ON to OFF. Brief and successive applications of the Parking Brake is now the recommended procedure and it has been published in the Abnormal & Emergency Procedures section of the Flight Crew Operating Manual Vol. 3.

2.2.2. Evacuation of the aircraft.

The passengers seemed reluctant to open the over-wing exit hatches, preferring to use the main cabin doors and slides. The congestion in the aisle precluded the rear cabin crew member reaching these exits to direct their opening. This could have lost valuable time had any fire been present after the aircraft stopped.

The evacuation was delayed somewhat by the passengers attempting to collect hand luggage and by not using the over-wing exits, but was achieved apparently around the specified maximum time of 90 seconds. The post-evacuation handling of the passengers did not appear to have proceeded smoothly and there was a significant delay in the arrival of medical assistance for the one passenger suffering an asthma attack.

3. CONCLUSIONS.

3.1. Findings.

1. The crew was qualified for the flight and had valid licences.

2. The aircraft had been maintained in accordance with the established Maintenance Schedule and had a Certificate of Airworthiness in force.

3. When the handling pilot selected Autobrake LO an internal fault occurred within both BSCU channels. This fault left the system inoperative for the brake function through the Normal Braking system.

4. The crew was aware of a BSCU internal fault. The information contained in the FCOM-Abnormal and Emergency procedures, did not require any further action by the crew or provide any additional information. However in FCOM-Supplementary Techniques, there was a procedure to reset the BSCU computer.

5. In spite of the presence of an internal fault in both BSCU channels, the aircraft still should have had braking capability through the Alternate Brake System.

6. When the crew operated the brake pedals, the Alternate Braking system did not function. This was due to a dormant condition within the BDDV which had been present for an unidentified period.

7. The malfunction of the BDDV occurred as a result of the presence of water and detergent mixture which had frozen due to the low external temperature during the cruise and had not melted in the relatively short descent period. This prevented the movement of the rocker assembly in the lower part of the valve.

8. The commander, faced with the impossibility of stopping the aircraft within the stop-way, sensibly chose to swerve the aircraft from side to side and, above all, to turn to the right hand side of the runway in order to prevent the aircraft from running into the Mediterranean sea.

9. The crew had not been trained on the use of the Parking Brake as a last resort in the event of an emergency when the Normal and Alternate Braking systems were lost. This training deficiency was widespread in the standard training courses for the pilots of these aircraft.

3.2. Causes.

The accident was caused by the lack of availability of both the Normal and the Alternate Brake systems during the landing roll.

The loss of the Normal Braking system occurred as a result of a logic disagreement in both channels of BSCU caused by the acquisition of the AUTO/BRK LO input.

The automatic transfer to the Alternate Braking system did not occur as a result of the BDDV failed to function because of the presence of a frozen aqueous solution in its lower cover.

The deficiencies of the FCOM concerning the emergency procedures to be followed in these two failures, and the deficiencies of the flight crew training, contributed to the aircraft running out of the runway.

4. SAFETY RECOMMENDATIONS.

I. The initial event was the disagree condition experienced on **both** channels of the BSCU at Autobrake selection. However, only the first disagree occurrence (BRAKES BSCU CH2 FAULT) was annunciated to the crew via the ECAM. The presence of the second BSCU CH1 disagree was stored in the CFDIU failure messages but was not transmitted to the ECAM. The crew was therefore not given a complete indication of the true state of the aircraft system by the ECAM. It is therefore recommended that Airbus Industrie improve the ECAM indication logic such that a full and accurate indication is available to the crew about the true status of the BSCU system, and its effect upon the availability of the Normal Braking System at touchdown.

II. The FCOM reference for the single Channel Fault indicated that it was for 'crew awareness' only. Thus, the FCOM material did not assist the crew in troubleshooting the initial event and there was no reference to the Supplementary Techniques which could have been applicable. It is therefore recommended to Airbus Industrie that when 'Crew Awareness' is indicated in the FCOM, additional references to relevant FCOM information should be provided.

III. The possibility existed that the crew could have reset the BSCU after the initial Autobrake selection. However, under certain conditions, it would not be prudent to conduct a BSCU reset. It is therefore recommended that Airbus Industrie clearly define in the FCOM the conditions under which a BSCU reset is permitted.

IV. The main BSCU switch is currently named A/SKID & N/W STRG. This does not fully reflect the effect of its operation, i.e. a reset of the BSCU computer. It is therefore recommended that Airbus Industrie change the name of the A/SKID & N/W STRG switch to a fully describe its function as a A/SKID, N/W STRG & BSCU switch.

V. BSCU computer software standard 8, superseded by standard 9, introduced improvements to avoid the logic disagreement condition when selecting the Autobrake LO or MED modes. It is therefore recommended to the Certification Authority (DGAC) that it should evaluate the suitability of making mandatory its implementation.

VI. At touchdown the Normal Braking System was lost. The appropriate warning to the crew was inhibited during the landing phase. It is therefore recommended to Airbus Industrie that warning messages about any change in the status of the braking system during the landing phase be immediately communicated to the crew via the ECAM Warning system without delay.

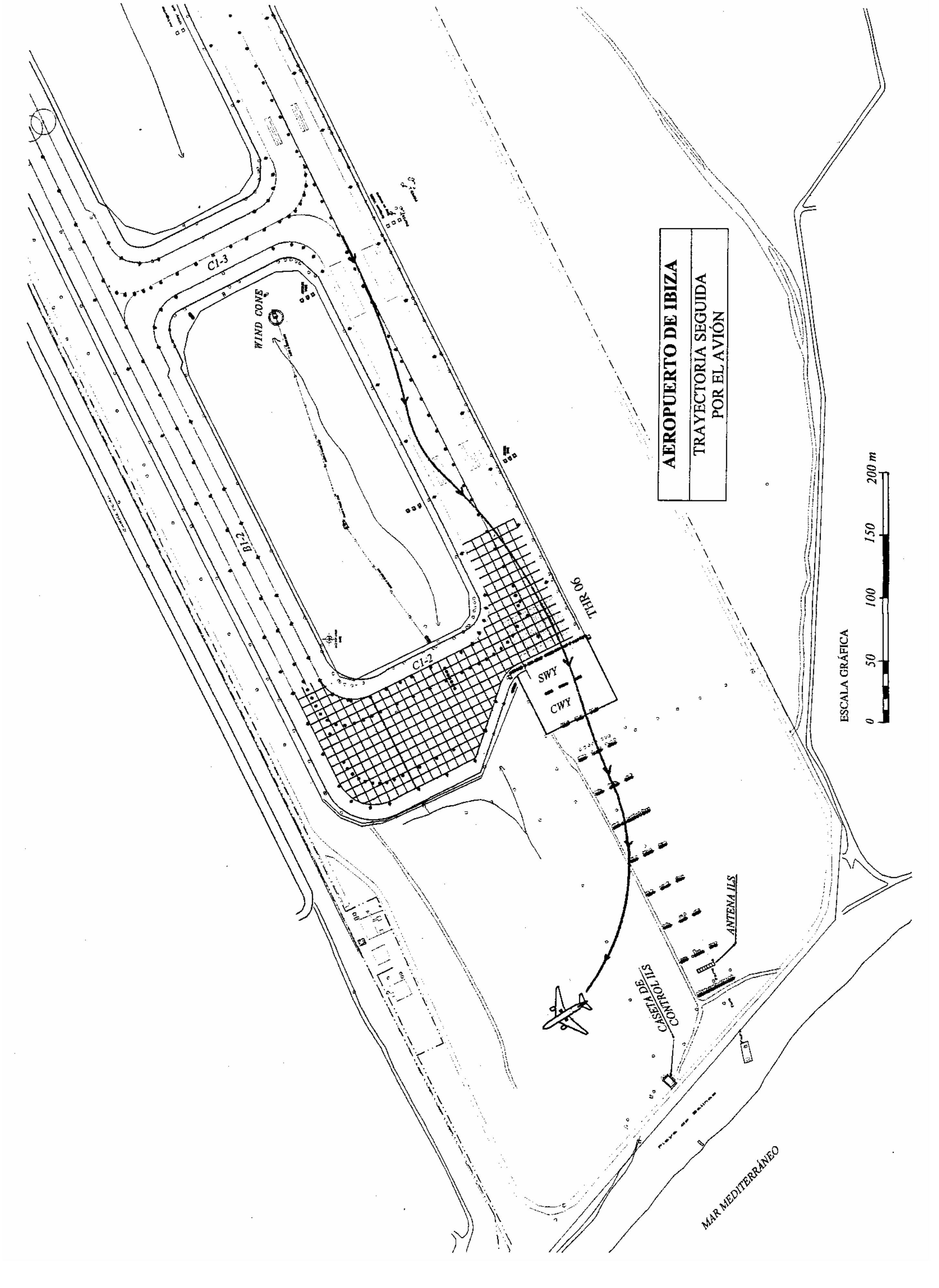
VII. The warning message which would have been transmitted, BRAKES AUTO BRAKE FAULT only describes the Autobrake fault and not the resulting loss of the Normal Brake system. It is therefore recommended to Airbus Industrie that the loss of the Normal Brake System should be clearly indicated to the crew through an ECAM Warning message.

VIII. With the loss of the Normal and Alternate Braking System it was still possible to stop the aircraft using the Parking Brake. However the crew were not trained in this technique. It is therefore recommended to Airbus Industrie that they include the technique for use of the Parking Brake as an Emergency Brake in a flight simulator demonstration during the pilot training syllabus.

IX. If the Parking Brake is available to be used as an Emergency Braking device, then it is recommended that Airbus Industrie should rename it as a Parking and Emergency Brake to highlight its use in such a manner.

APPENDIX A

Path followed by the aircraft.


AEROPUERTO DE IBIZA
TRAYECTORIA SEGUIDA POR EL AVIÓN
ESCALA GRÁFICA
0
50
100
150
200 m
THR 06
SWY
CWY
C1-3
C1-2
B1-2
WIND CONE
ANTENA ILS
CASETA DE CONTROL ILS
MAR MEDITERRÁNEO

APPENDIX B

Description of the Braking System, schematics, warning messages, supplementary techniques, and emergency procedure.

DESCRIPTION

GENERAL

The main wheels have multidisc brakes that can be actuated by either of two independent brake systems.
The normal system uses green hydraulic pressure : the alternate system uses the yellow hydraulic system backed up by a hydraulic accumulator.
An anti-skid system and autobraking work through the brake system.
Braking commands come from either the brake pedals (pilot action) or the autobrake system (deceleration rate selected by the crew).
Two units on each main gear monitor the temperature of the brakes.
All braking functions (normal and alternate braking control, anti-skid control, autobraking, brake temperature indication) are controlled by a two-channel Brake and Steering Control Unit (BSCU).
The main wheels have fusible plugs that prevent the tires from bursting if they overheat.
The main wheels may also have brake cooling fans. ◁

ANTI-SKID SYSTEM

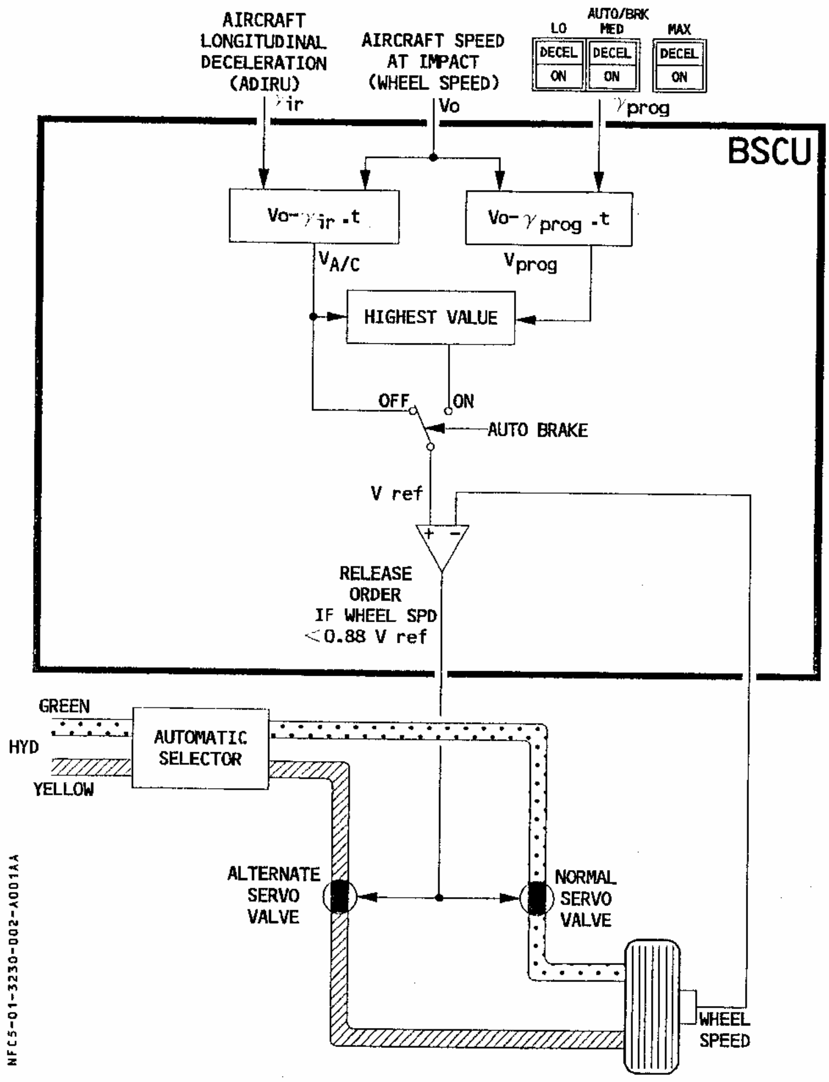
The anti-skid system produces maximum braking efficiency by maintaining the wheels just short of an impending skid.
When a wheel is on the verge of locking, the system sends brake release orders to the normal and alternate servovalves — and to the ECAM, which displays the released brakes.
The anti-skid deactivates when ground speed is less than 20 knots.
An ON/OFF switch turns the anti-skid system and nose wheel steering on and off.

PRINCIPLE

The system compares the speed of each main gear wheel (given by a tachometer) with the speed of the aircraft (reference speed). When the speed of a wheel drops below 0.87 times the reference speed, the system orders brake releasing in order to maintain the brake slip at that value (best braking efficiency).
In normal operation, the BSCU determines the reference speed from the horizontal acceleration furnished by ADIRU1 or ADIRU3.
R If ADIRU 1 and ADIRU 3 fail, reference speed equals the greater of either main landing gear wheel speed. Deceleration is limited to 1.7 meters/second^2 (5.6 feet/second^2)

ANTI-SKID PRINCIPLE

FOR INFO



AUTO BRAKE

The purposes of this system are :
- to reduce the braking distance in case of an aborted takeoff
- to establish and maintain a selected deceleration rate during landing, thereby improving passenger comfort and reducing crew workload.

ARMING

The system arms when the crew presses the LO, MED, or MAX pushbutton switch if :
- Green pressure is available.
- The anti-skid system has electric power.
- There is no failure in the braking system.
- At least one ADIRS is functioning.

Note : Auto brake may be armed with the parking brake on.

ACTIVATION

Automatic braking commences when the ground spoilers extend (Refer to 1.27.10 SPEED BRAKES AND GROUND SPOILERS). Therefore, if the aircraft makes an acceleration stop and begins to decelerate when its speed is under 72 knots, the automatic braking will not function because the ground spoilers will not extend.
For autobrake to activate, at least two SEC's must be operative.

DISARMING

The system disarms when :
- Flight crew presses the pushbutton switch or,
- One or more arming conditions is lost or,
R - Flight crew applies enough deflection to one brake pedal when autobrake is operating in MAX, MED or LO mode.
- The ground spoilers retract (Refer to 1.27.10).
- The aircraft has been in flight for 10 seconds.

OPERATION

There are four modes of operation :
- Normal braking,
- Alternate braking with anti-skid,
- Alternate braking without anti-skid,
- Parking brake.

NORMAL BRAKING

Braking is normal when :
- Green hydraulic pressure is available.
- The A/SKID & N/W STRG switch is ON.
- The parking brake is not ON.

During normal braking, anti-skid operates and autobrake is available.
Braking is controlled electrically through the BSCU :
- from the pilot's pedals or,
- automatically
  - on the ground by the autobrake system,
  - in flight when the landing gear lever is up.

The anti-skid system is controlled by the BSCU via the normal servo valves.
There is no indication of brake pressure in the cockpit.

ALTERNATE BRAKING WITH ANTI-SKID

Braking uses this mode when green hydraulic pressure is insufficient and :
- Yellow hydraulic pressure is available.
- The A/SKID & N/W STRG switch is ON.
- The parking brake is not ON.

An automatic hydraulic selector changes from the green to the yellow system.
The pedals brake through the auxiliary low-pressure hydraulic distribution line acting on the dual valves. The BSCU controls the anti-skid system via the alternate servo valves.
A triple indicator on the center instrument panel shows the pressure delivered to the left and right brakes, as well as the accumulator pressure.
Autobrake is inoperative.

ALTERNATE BRAKING WITHOUT ANTI-SKID

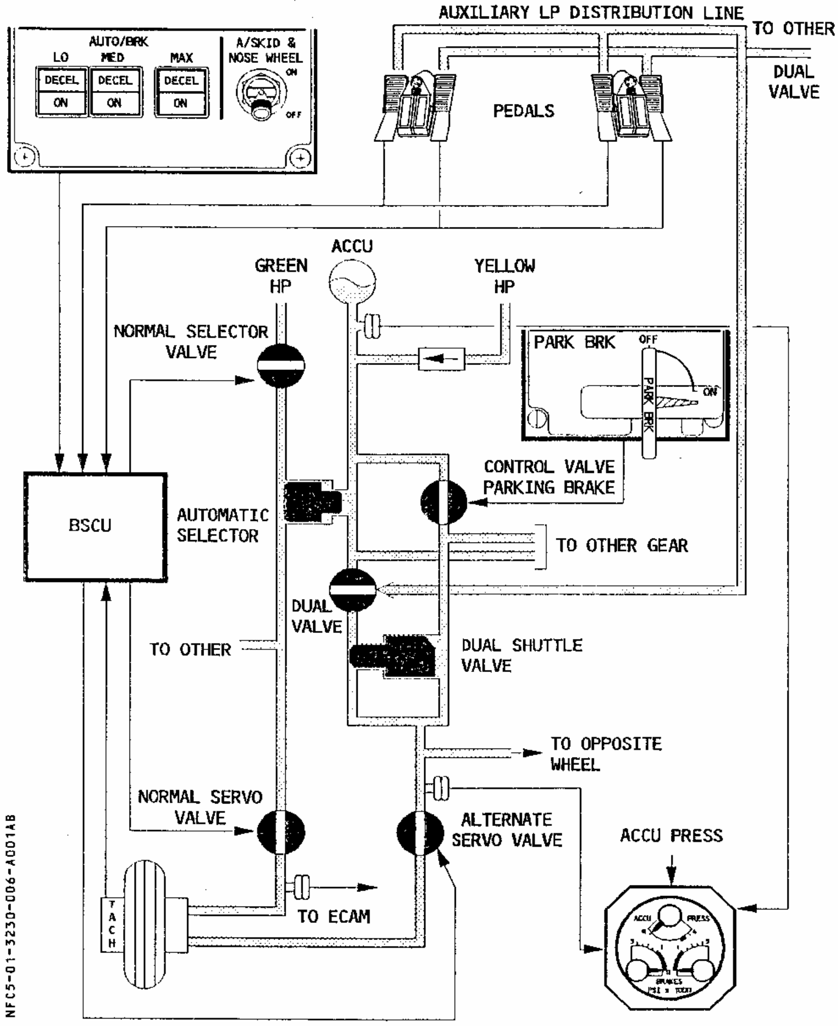
The anti-skid system can be deactivated :
- electrically (A/SKID & N/W STRG switch OFF, or power failure or BSCU failure),
- hydraulically (low pressure in both green and yellow systems, brakes being supplied by the brake accumulators only).

The pilot controls the braking with the pedals (acting on the dual valves).
Alternate servo valves are fully open.
The pilot must refer to the triple indicator to limit brake pressure in order to avoid locking a wheel.
The accumulator can supply at least 7 full brake applications.
Autobrake is inoperative.

PARKING BRAKE

Putting on the PARKING BRK deactivates the other braking modes and the anti-skid system.
The yellow hydraulic system or accumulators supply brake pressure via the dual shuttle valves. Alternate servo valves open to allow the application of full pressure.
Accumulators maintain the parking pressure for at least 12 hours.
Crew members can pressurize the yellow accumulators by pressing the yellow electric pump switch.
The triple indicator shows brake pressure.

BRAKING SCHEMATIC



CONTROLS AND INDICATORS

CENTER INSTRUMENT PANEL

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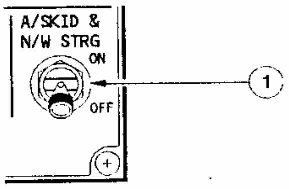


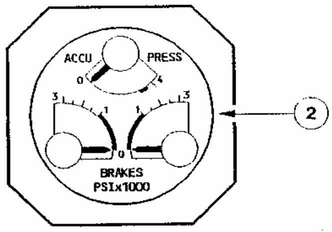
(1) A/SKID & N/W STRG sw

ON : If green hydraulic pressure is available :
- Anti-skid is available.
- Nose wheel steering is available.

If green hydraulic pressure is lost :
- Yellow hydraulic pressure takes over automatically to supply the brakes.
- Anti-skid remains available.
- Nose wheel steering is lost.
- The triple indicator shows yellow system brake pressure.

OFF : Yellow hydraulic system supplies pressure to the brakes.
- Anti-skid is deactivated. The pilot must refer to the triple indicator to limit brake pressure and avoid locking a wheel.
- Nose wheel steering is lost.
- Differential braking remains available through the pedals.
- The triple indicator displays yellow system brake pressure.

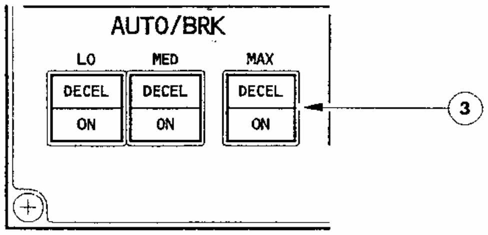
NFC5-01-3230-007-B001AA



(2) BRAKES and ACCU PRESS indicator

ACCU PRESS : Indicates the pressure in the yellow brake accumulators.
BRAKES : Indicates the yellow pressure delivered to the left and right brakes, as measured upstream of the alternate servo valves.

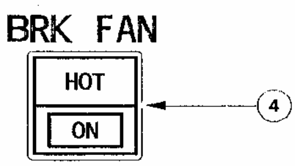
AUTO BRK panel



(3) AUTO/BRK panel

The springloaded MAX, MED, and LO pushbutton switches arm the appropriate deceleration rate.

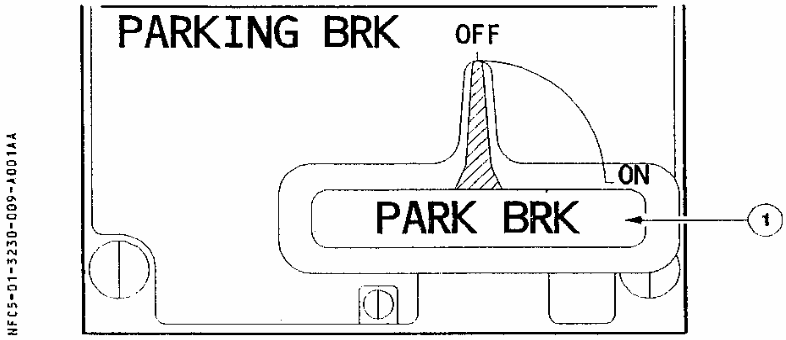
- MAX mode is normally selected for takeoff.
  If the pilot aborts the takeoff, maximum pressure goes to the brakes as soon as the system generates the ground spoiler deployment order.
- MED or LO mode is normally selected for landing.
  - LO mode sends progressive pressure to the brakes 4 seconds after the ground spoilers deploy in order to decelerate the aircraft at 1.7 meters/second^2 (5.6 feet/second^2).
  - MED mode sends progressive pressure to the brakes 2 seconds after the ground spoilers deploy in order to decelerate the aircraft at 3 meters/second^2 (9.8 feet/second^2).
- Lights :
  - The blue ON light comes on to indicate positive arming.
  - The green DECEL light comes on when the actual deceleration is 80% of the selected rate.
  - Off : The indicated brake mode is not active.



(4) BRK FAN pb sw

ON : The brake fans run if the lefthand main landing gear is down and locked.
OFF : The brake fans stop.
HOT lt : This amber light comes on when the brakes get too hot. (A caution appears on ECAM, also).

PEDESTAL

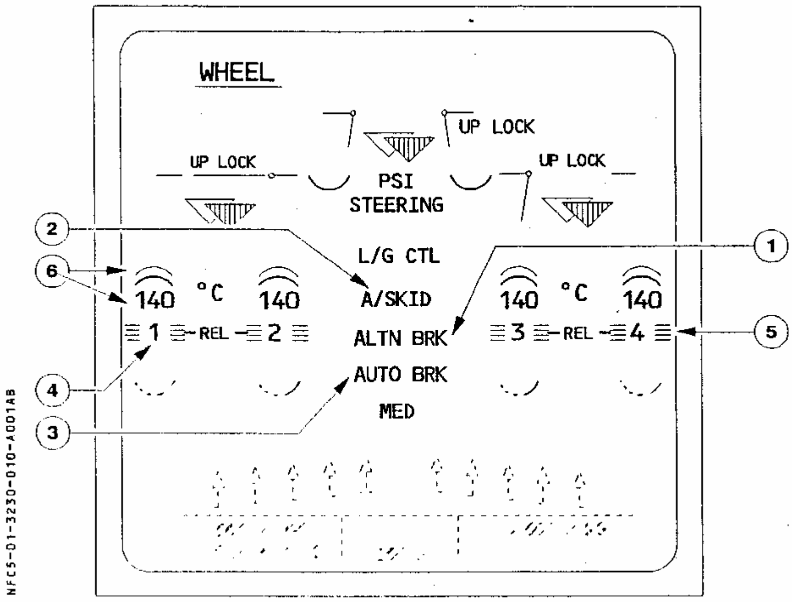


(1) PARKING BRK handle

Flight crew pulls this handle, then turns it clockwise, to apply the parking brake.
Applying the parking brake deactivates all the other braking modes.
The ECAM memo page displays "PARK BRK".

CAUTION
If the pointer is not at ON, the parking brake is not on.

ECAM WHEEL PAGE



① ALTN BRK

This legend appears in green if the braking system is in alternate mode.

② A/SKID

This legend appears in amber, along with an ECAM caution, in case of total BSCU failure, or when the A/SKID & N/W STRG switch is OFF, or if the BSCU detects an ANTI-SKID failure.

③ AUTO BRK

This legend appears :
– in green when auto brake is armed,
– flashing green for 10 seconds after autobrake disengagement,
– in amber, along with an ECAM caution, to indicate a system failure.
MED, LO, or MAX appears underneath in green to show which rate has been selected.

(4) Wheel number

This white number identifies individual wheels of the main landing gear.

(5) Release indicators

≡ These green lines appear temporarily after the landing gear has been lowered to indicate that the anti-skid function is ready.
They reappear after touchdown, along with REL (blue), when the anti-skid is active.

(6) Brake temperature

- The temperature normally appears in green.
- The green arc appears on the hottest wheel when one brake temperature exceeds 100°C.
- The green arc becomes amber, and an ECAM caution appears, when the corresponding brake temperature exceeds 300°C.

WARNINGS AND CAUTIONS

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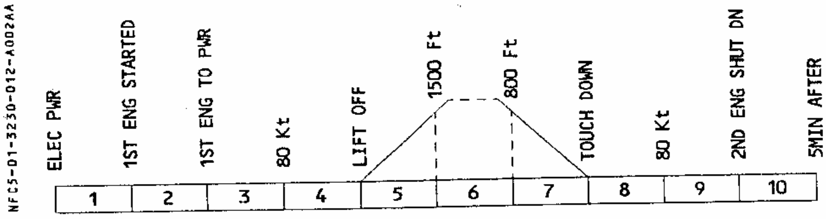


E/WD : FAILURE TITLE condition	AURAL WARNING	MASTER LIGHT	SD PAGE CALLED	LOCAL WARNING	FLT PHASE INHIB
CONFIG PARK BRK ON parking brake is on when thrust levers are set at TO or FLX TO power position	CRC	MASTER WARN	NIL	NIL	1, 2 5 to 10
BRAKES HOT one brake temperature higher than 300°C	SINGLE CHIME	MASTER CAUT	WHEEL	HOT lt on BRK FAN pb sw	4, 8
AUTO BRK FAULT failure of autobrake when armed	SINGLE CHIME	MASTER CAUT	WHEEL	NIL	3 to 5, 8, 9
A/SKID NWS FAULT · loss of normal brake system associated with Y HYD sys lo press or · failure of both BSCU channels	SINGLE CHIME	MASTER CAUT	WHEEL	NIL	4, 5
ANTI SKID/NWS OFF switch at OFF position	SINGLE CHIME	MASTER CAUT	WHEEL	NIL	4, 5, 9
HYD SEL FAULT failure of brake normal selector valve or NWS selector valve in open position	SINGLE CHIME	MASTER CAUT	NIL	NIL	3 to 5, 7, 8
BSCU CH 1 (2) FAULT failure of one BSCU channel	NIL	NIL	NIL	NIL	3 to 5, 7, 8

MEMO DISPLAY

- If the parking brake is on, this display shows "PARK BRK" :
  - in green in flight phases 1, 2, 9, and 10.
  - in amber in flight phases 4 to 8.

  It does not display this message in flight phase 3.
- If the autobrake is ON, "AUTO BRK LO", "AUTO BRK MED", or "AUTO BRK MAX" appears.
- If the autobrake is faulty, "AUTO BRK OFF" appears.
- "BRK FAN" appears in green if the BRK FAN pushbutton switch is ON. ◁

BUS EQUIPMENT LIST

		NORM		EMER ELEC		
		AC	DC	AC ESS	DC ESS	HOT
LANDING GEAR	LGCIU 1		GRND/ FLT		X	
	LGCIU 2		GRND/ FLT			
	SAFETY VALVE				X	
	L/G INDICATOR PANEL			SHED (1)		
BRAKES	BSCU CH 1	AC1	DC1			
	BSCU CH 2	AC2	DC2			
	PARK BRK CTL		GRND/ FLT			HOT1
	PRESS INDICATOR				X	
	BRK FAN CTL ◁		DC2			
	COOLING FANS ◁ (Wheels 1, 2, 3, 4)	AC2				
	COOLING FANS ◁ (bogie : Wheels 5, 6, 7, 8)	AC1				
TYRE PRESS	TIRE PRESS IND UNIT ◁		DC1			

(1) The AC STAT INV supplies the landing gear indicator panel when the main generators are lost and the emergency generator is not running.

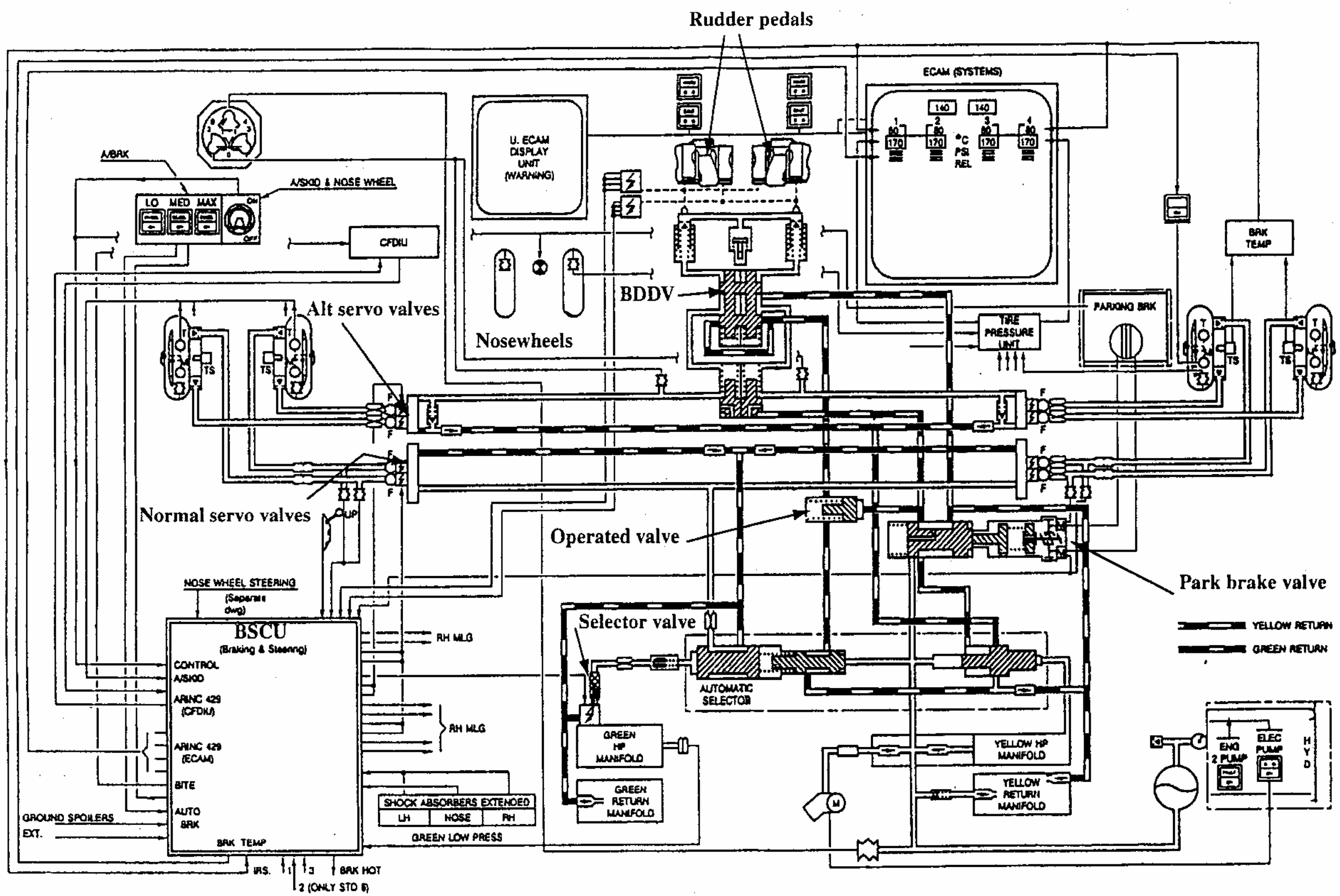


FIGURE 1 A320 BRAKING SYSTEM SCHEMATIC

(Adapted from an Aerospatiale Technical Note)

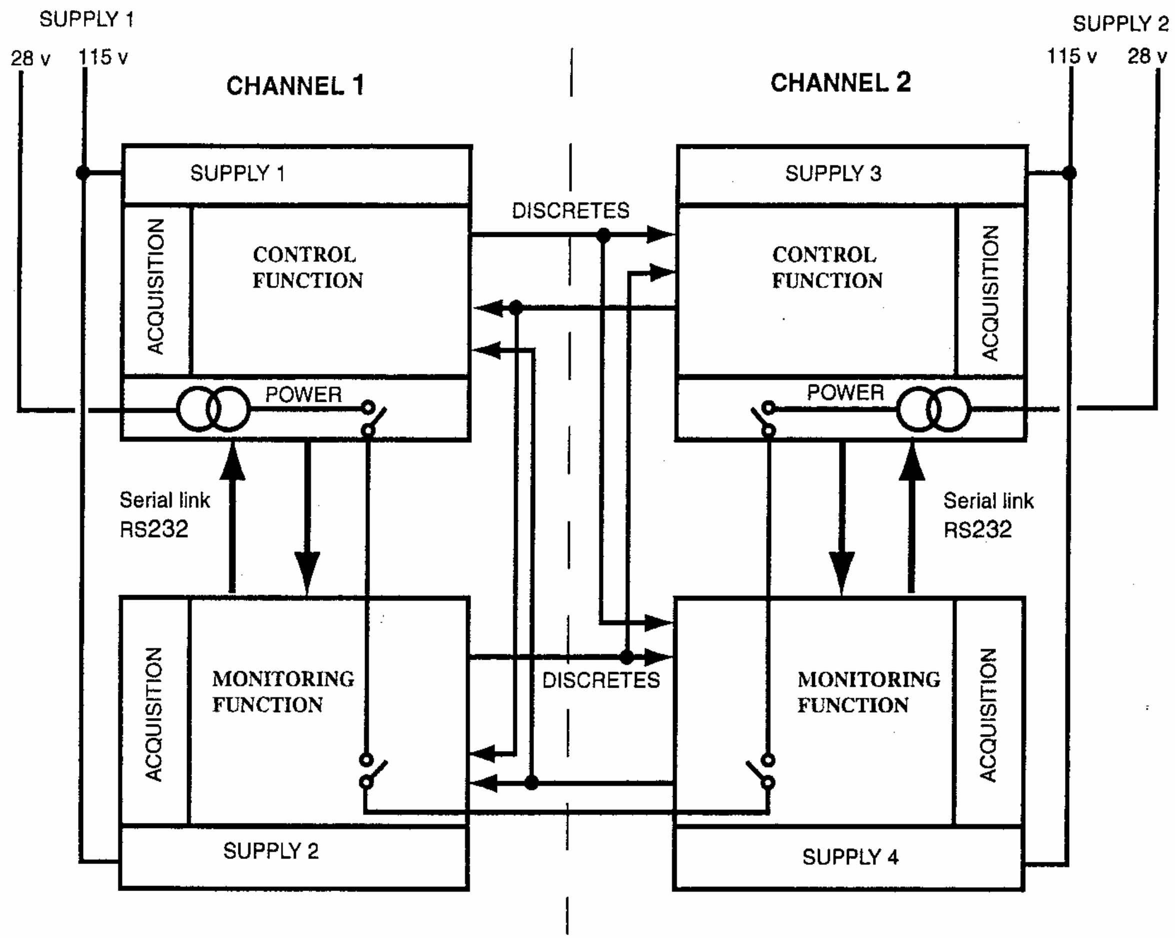


FIGURE 2. BSCU FUNCTION SCHEMATIC

COMPUTER RESET

The normal functions of a Circuit Breaker (C/B) are to protect wiring against short circuits and to isolate equipment for maintenance.
Another function has developed for circuit breakers in digital computers : the reset function. When a digital computer behaves abnormally, as a result of an electrical transient, for example, the operator can stop the abnormal behaviour by interrupting the power supply to its processor for a short time (approximately 10 seconds).
The flight crew can reset most of the computers in this aircraft with a normal cockpit control (selector or pushbutton). However, for some systems the only way to cut off electrical power is to pull the associated circuit breaker.

PROCEDURE

The flight crew pulls the relevant circuit breaker (C/B), waits at least 5 seconds, then pushes it in again (in most cases before 10 seconds have elapsed).
Generally, the flight crew should reset one computer at a time.

On the ground

The flight crew can if necessary reset any computer except :
- ECU (Engine Control Unit on CFM engines) or EEC (Electronic Engine Control on IAE engines) and EIU (Engine Interface Unit) while the engine is running.
- BSCU (Brake Steering Control Unit) if the aircraft is not stopped. (Refer to 3.04.32).

In flight

As a general rule, the crew must restrict its resetting of circuit breakers to those listed in the table or in applicable Temporary Revisions (TRs) or in applicable Operations Engineering Bulletins (OEBs).
Before taking any action on other C/Bs, the flight crew must consider and fully understand the consequences.

CAUTION
Do not pull the following circuit breakers :
– SFCC (could lead to SLATS/FLAPS locked)
– ECU or EEC, EIU.

R

MCDU FMGC	Refer to 4.06.10
CIDS	Pull in parallel the following C/B's and reset after not less than 10 seconds : – DIR 1 and 2/ESS . . . . G2 or G1 + G2 ◁ on 49 VU – DIR 1 and 2/NORM . . . . M5 or M6 + M7◁ on 121 VU – DIR 1 and 2/BAT . . . . N11 ◁ on 121 VU
FWC	Pull then push C/B of affected FWC – FWC 1 . . . . E2 or F01 (◁) ON 49 VU – FWC 2 . . . . Q7 ON 121 VU
BSCU	Refer to 3.04.32
ELAC or SEC	Reset of flight control computers is possible in flight, even if not requested by the ECAM, provided only one reset is performed at a time. For the ELAC only, the reset is not recommended in case of uncommanded maneuvers in flight.

BRAKING

If the brakes fail during ground operations switch the A/SKID & N/W STRG switch to OFF immediately. Brake pedals should be released when the antiskid is switched off. Otherwise, the pedal braking orders will be taken into account and the aircraft will react strongly. Modulate brake pressure as required at or below 1000 psi. Steer the aircraft with differential braking as nose wheel steering is lost.
In an extreme emergency, and only if brake pedals are ineffective with the antiskid off, the pilot may select the parking brake on (full pressure is applied).

BRAKING IN ALTERNATE MODE

Apply brakes with care since initial pedal force or displacement produces more braking action in alternate mode than in normal mode.

BSCU RESET

R In case of braking/steering difficulty, the crew may perform a reset of the BSCU to recover
R a correct functioning of the system. This applies in particular in case of either following
R ECAM warning :

WHEEL N.W. STEER FAULT
BRAKES AUTO BRAKE FAULT (except in flight)
BRAKES BSCU CH1 (2) FAULT

- On ground, aircraft stopped, by switching OFF then ON the A/SKID & N/W STRG selector.

Note : BSCU reset on ground while the aircraft is moving is not recommended. However, in case of loss of both BSCU channels during landing roll and if the crew cannot maintain the aircraft on the runway by using the flight controls and the alternate braking system, a reset of BSCU throught the A/SKID & N/W STRG selector may be attempted.
During the reset :
- *Nose wheel steering should be at neutral*
- *Rudder pedals should be at neutral*
- *Brake pedals should be released.*

Otherwise the associated steering and braking orders will be taken into account by the BSCU and the aircraft may react strongly and suddenly to these orders.

- In flight, with landing gear retracted, by switching OFF then ON the A/SKID & N/W STRG selector.

Reset should not be performed in flight in case of AUTO BRAKE FAULT to avoid to clear a real tachometer failure (no tachometer test in flight).
If required, the autobrake has to be rearmed.

LOSS OF BRAKING

In case of loss of braking efficiency on normal system without ECAM warning immediately select the A/SKID & N/W STRG selector to OFF, and modulate the brakes pressure with the pedals as required at or below 1000 psi. Nose wheel steering is lost and the aircraft is steered with differential braking. In an extreme emergency, and only if pedals are ineffective with the antiskid off, the aircraft may be stopped with the parking brake (full pressure application will occur).

CONFIG PARK BRAKE ON

Check that the parking brake handle is in the OFF position. If warning stays on, check that the brake pressure is at zero on the BRAKES PRESSURE indicator.

WHEEL N.W. STEER FAULT

CAT 3 SINGLE ONLY

STATUS

INOP SYS
CAT 3 DUAL
N.W. STEER

BRAKES A/SKID NWS FAULT or ANTI SKID/NWS OFF

Either both BSCU channels are failed or A/SKID & NOSE WHEEL switch is at OFF.

MAX BRK PR .... 1000 PSI

Monitor brake pressure on BRAKES PRESS indicator. Limit brake pressure to approximately 1000 psi and at low ground speed adjust brake pressure as required.
Avoid landing on an icy runway.

STATUS

MAX BRK PR .... 1000 PSI
LDG DIST .... × 1.5
CAT 3 SINGLE ONLY
Note : Autobrake is lost.

INOP SYS
CAT 3 DUAL
ANTI SKID
N.W. STEER
BRAKES CH 1
BRAKES CH 2

BRAKES BSCU CH 1(2) FAULT

Crew awareness

STATUS

INOP SYS
BRAKES CH 1(2)

APPENDIX C

DFDR internal fault photographs.

Figure 1

Figure 2

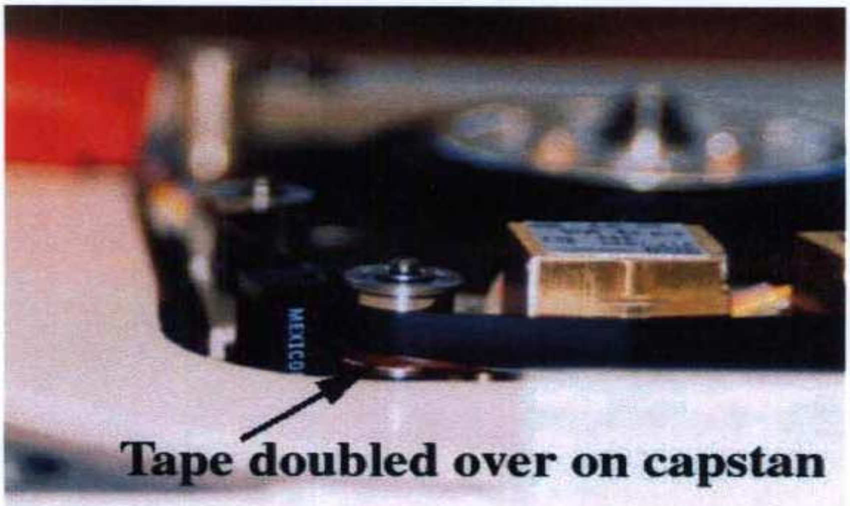
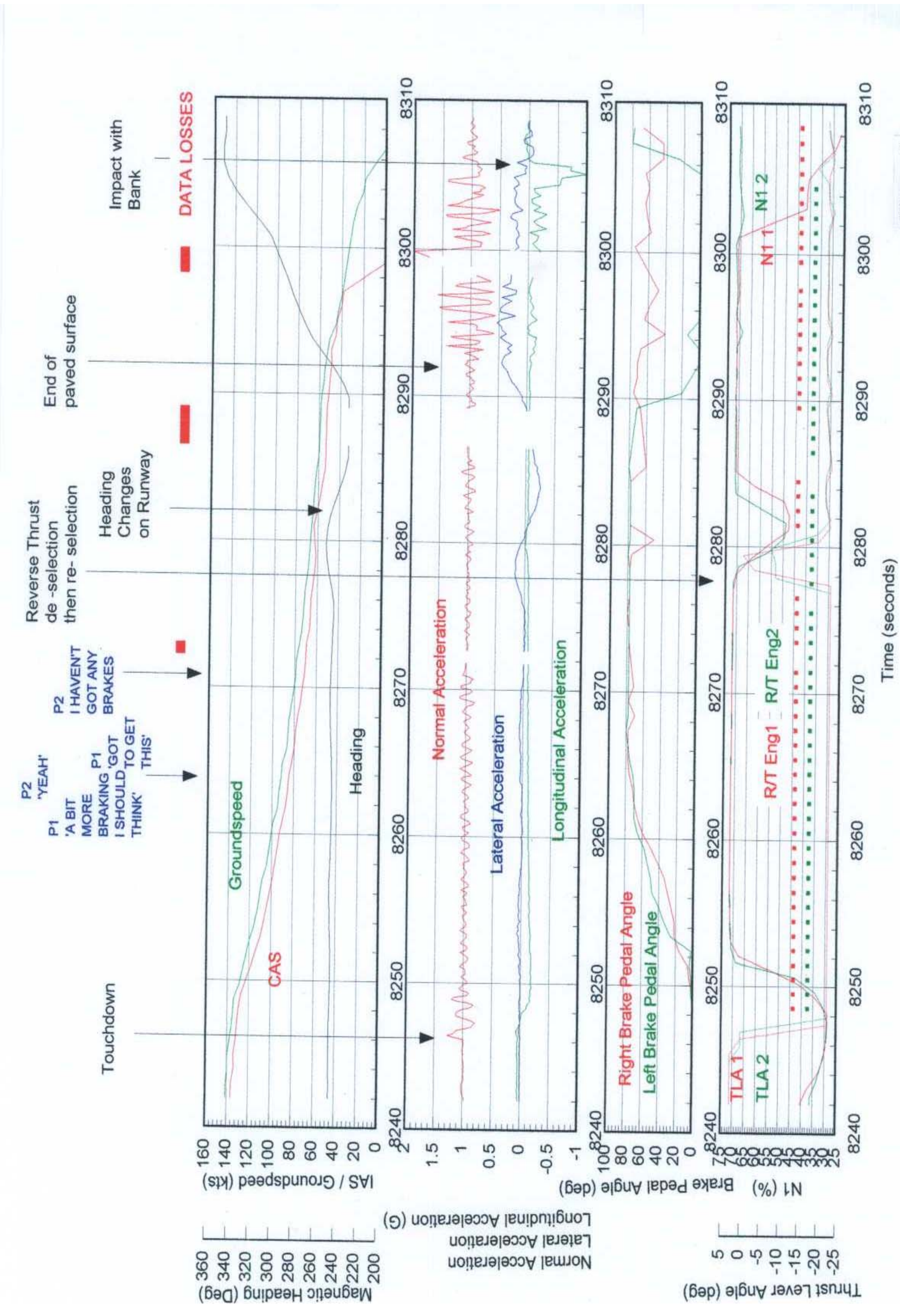


Figure 3

APPENDIX D

Charts obtained from DFDR data.



Touchdown
P1 'A BIT MORE BRAKING I SHOULD THINK'
P2 'YEAH'
P1 'GOT TO GET THIS'
P2 I HAVEN'T GOT ANY BRAKES
Reverse Thrust de -selection then re- selection
Heading Changes on Runway
End of paved surface
Impact with Bank
DATA LOSSES
Groundspeed
CAS
Heading
Normal Acceleration
Lateral Acceleration
Longitudinal Acceleration
Right Brake Pedal Angle
Left Brake Pedal Angle
TLA 1
TLA 2
R/T Eng1
R/T Eng2
N1 1
N1 2
IAS / Groundspeed (kts)
Magnetic Heading (Deg)
Longitudinal Acceleration (G)
Lateral Acceleration
Normal Acceleration
Brake Pedal Angle (deg)
N1 (%)
Thrust Lever Angle (deg)
Time (seconds)
8240
8250
8260
8270
8280
8290
8300
8310

Figure 1

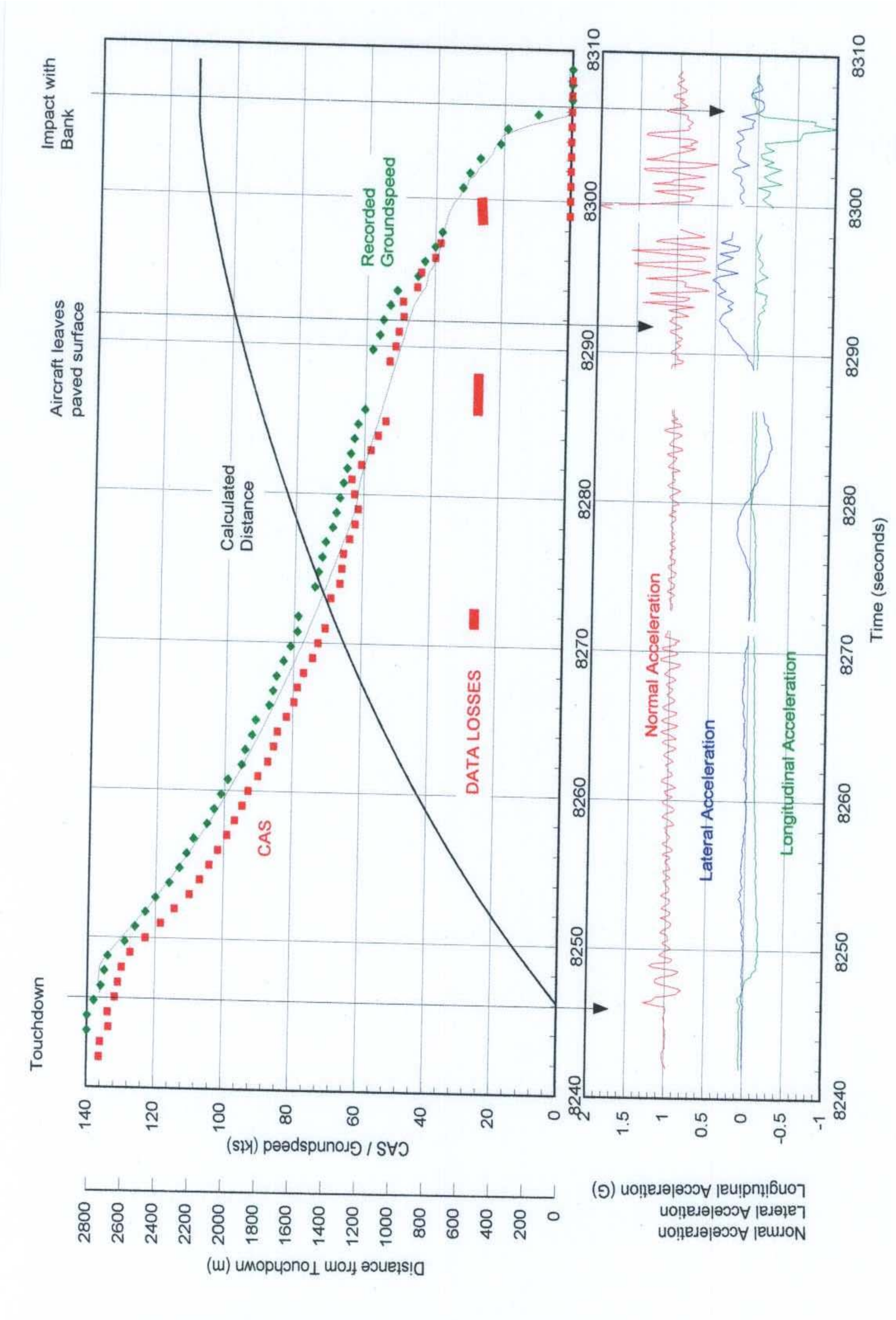
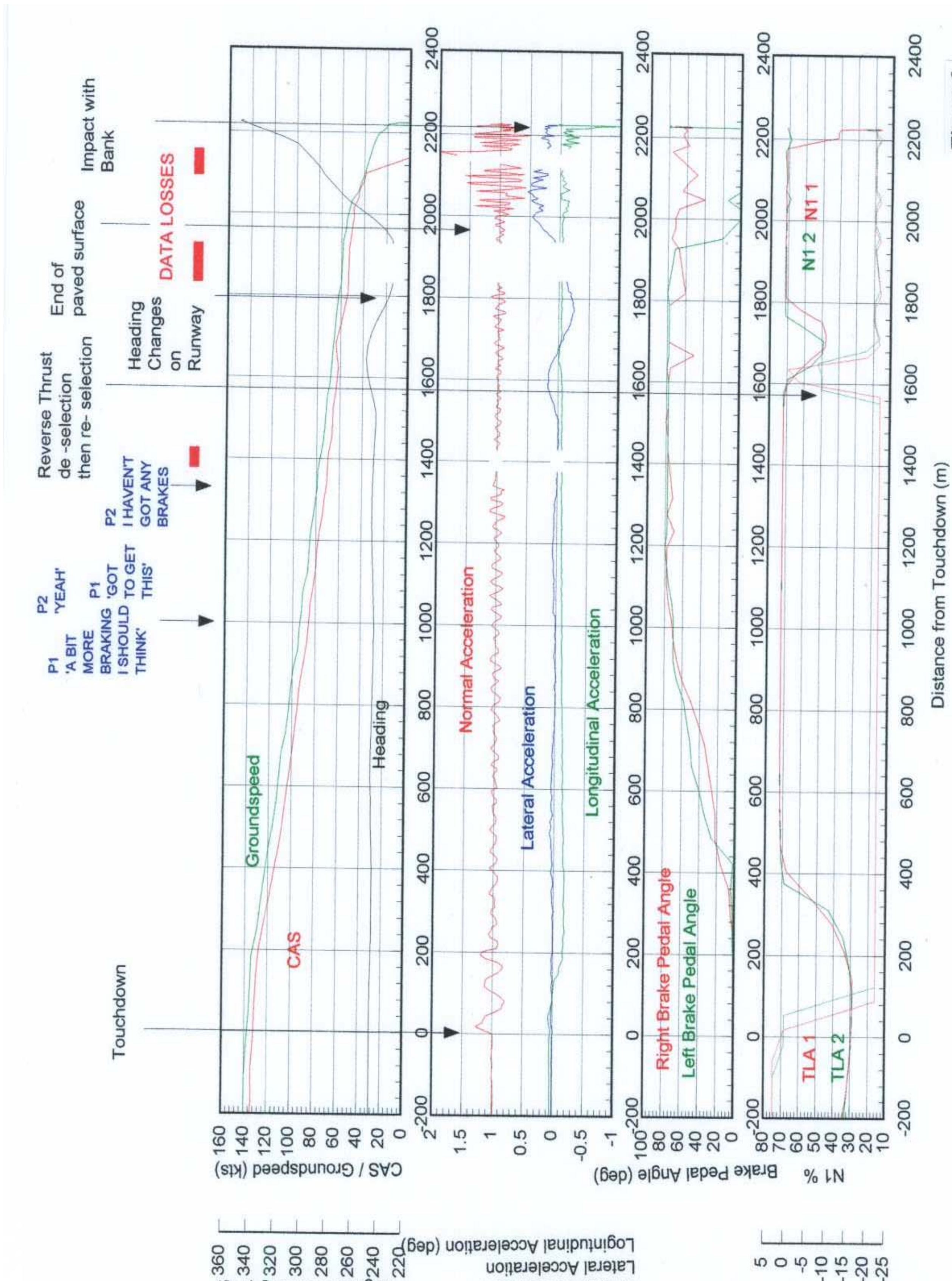

Touchdown
Aircraft leaves paved surface
Impact with Bank
Calculated Distance
Recorded Groundspeed
CAS
DATA LOSSES
Normal Acceleration
Lateral Acceleration
Longitudinal Acceleration
CAS / Groundspeed (kts)
Distance from Touchdown (m)
Normal Acceleration
Lateral Acceleration
Longitudinal Acceleration (G)
Time (seconds)
140
120
100
80
60
40
20
0
2800
2600
2400
2200
2000
1800
1600
1400
1200
1000
800
600
400
200
0
2
1.5
1
0.5
0
-0.5
-1
8240
8250
8260
8270
8280
8290
8300
8310

Figure 2



Touchdown
Reverse Thrust de -selection then re- selection
End of paved surface
Impact with Bank
P1 'A BIT MORE BRAKING I SHOULD THINK'
P2 'YEAH'
P1 'GOT TO GET THIS'
P2 I HAVEN'T GOT ANY BRAKES
Heading Changes on Runway
DATA LOSSES
Groundspeed
CAS
Heading
Normal Acceleration
Lateral Acceleration
Longitudinal Acceleration
Right Brake Pedal Angle
Left Brake Pedal Angle
TLA 1
TLA 2
N1 2
N1 1
CAS / Groundspeed (kts)
Magnetic Heading (deg)
Normal Acceleration
Lateral Acceleration
Loginitudinal Acceleration (deg)
Brake Pedal Angle (deg)
N1 %
Thrust Lever Angle (deg)
Distance from Touchdown (m)

Figure 3

APPENDIX E

Section of the BDDV and temperature charts of the in-flight tests.

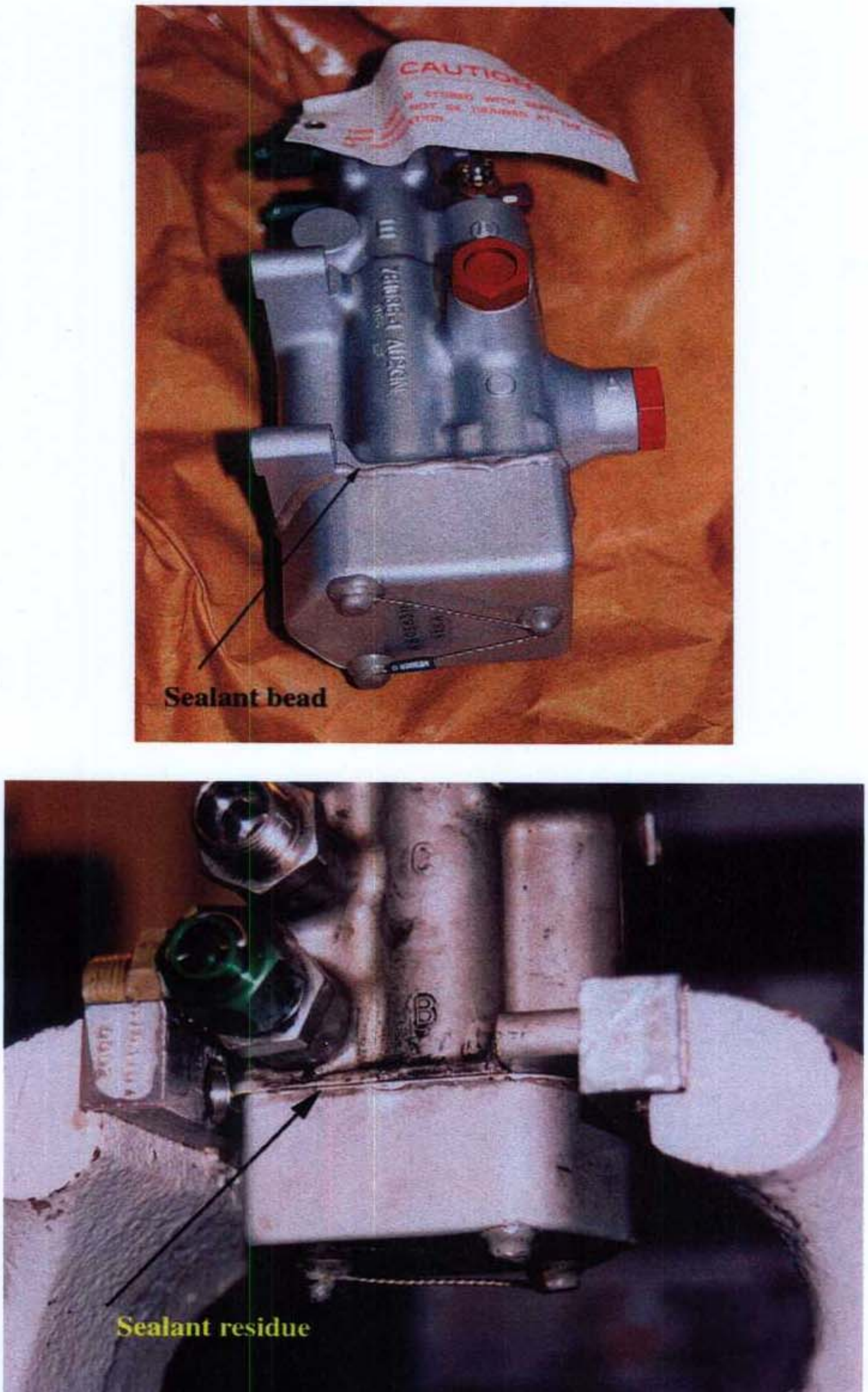


FIGURE 1. VIEW OF NEW BDDV TOGETHER WITH UNIT FROM G-UKLL

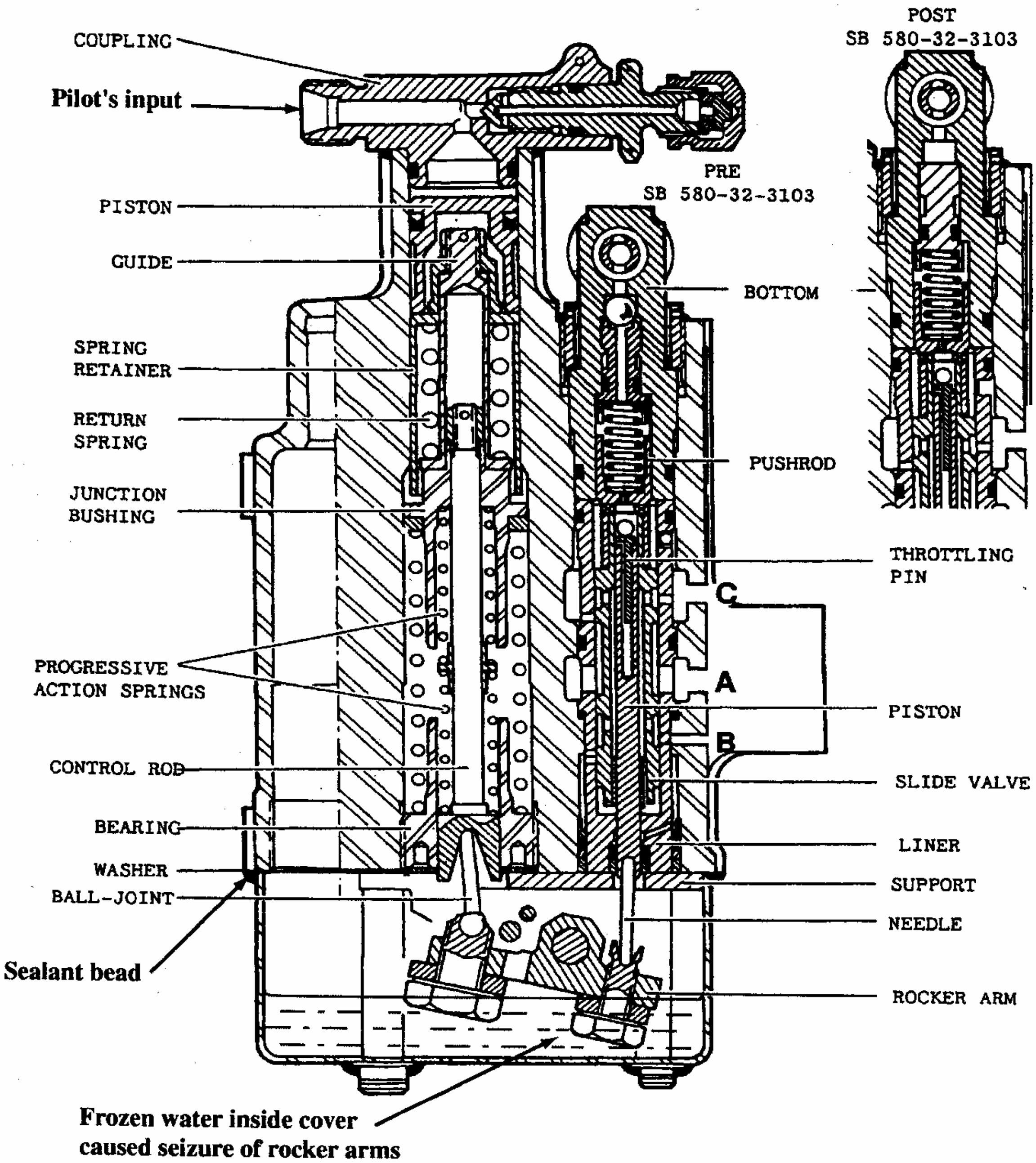


FIGURE 2 **SECTION THROUGH BDDV**
(Adapted from Messier-Bugatti diagram)

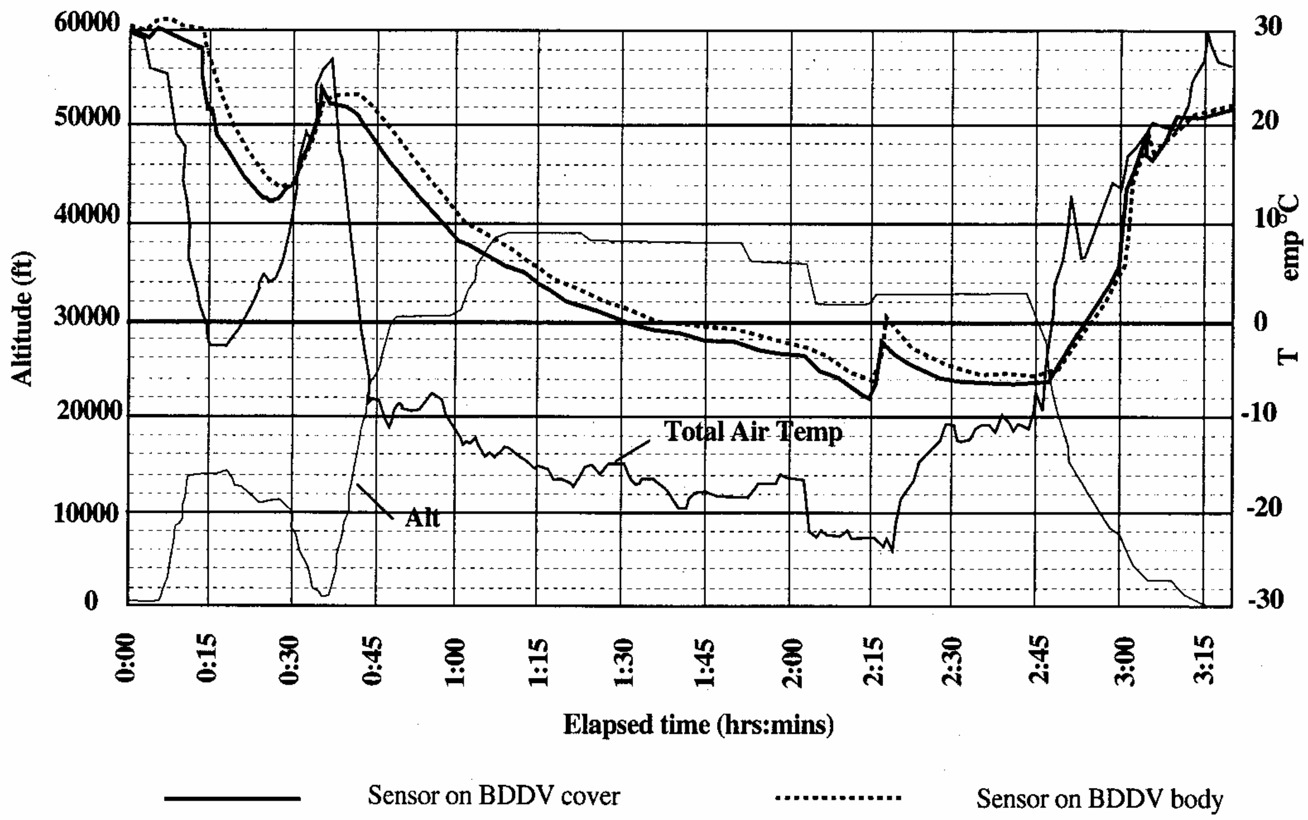


FIGURE 3. A320 BDDV TEMPERATURE MEASUREMENT TESTS

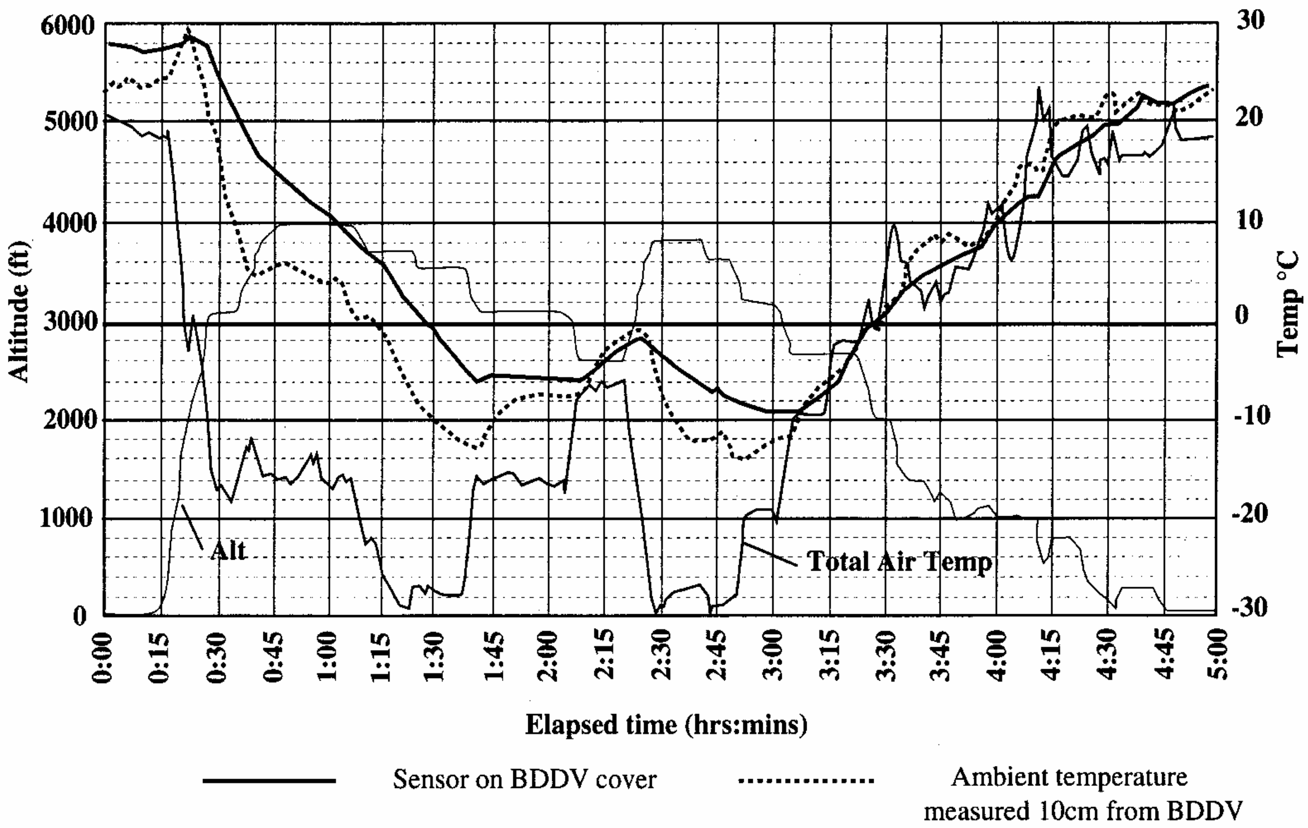
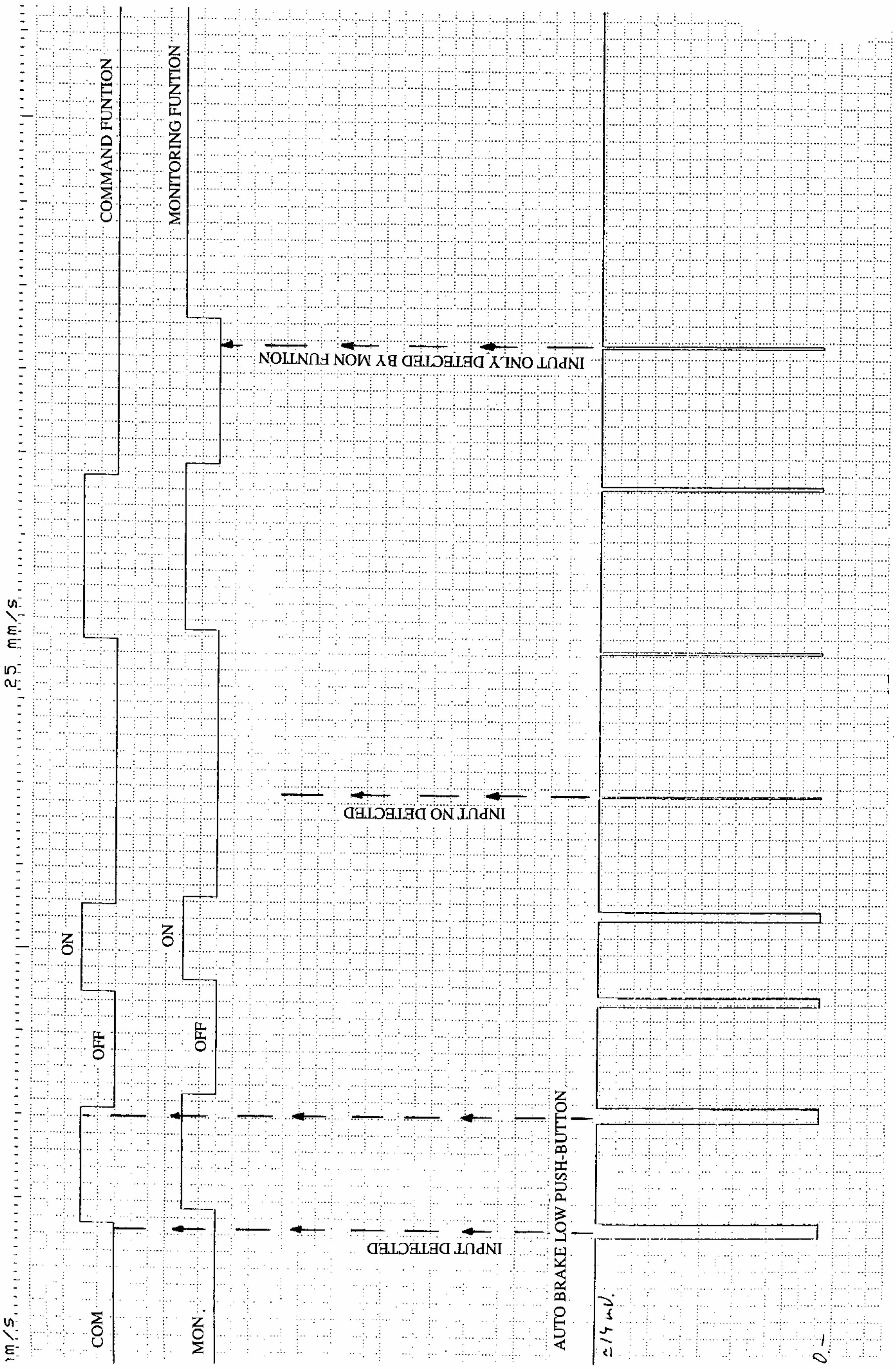


FIGURE 4. A300-600 BDDV TEMPERATURE MEASUREMENT TESTS

APPENDIX F

Oscilloscope chart of the pressing times of the AUTO/BRK LO and acquisition times by the command and monitor functions


25 mm/s
COMMAND FUNTION
MONITORING FUNTION
INPUT ONLY DETECTED BY MON FUNTION
INPUT NO DETECTED
INPUT DETECTED
AUTO BRAKE LOW PUSH-BUTTON
ON
OFF
ON
OFF
COM
MON

<u>APPENDIX G</u>

Copy of the Post Flight Report.

```
A/C ID    DATE    GMT    FLTN      CITY PAIR
.N445UA   25MAY   0910

+--------------------+
|    MAINTENANCE     |
| POST FLIGHT REPORT |
+--------------------+

A/C ID  DATE   GMT        FLTN       CITY PAIR
 G-UKLL  20MAY  2234/1147  4064       EGCC LEIB

ECAM WARNING MESSAGES
---------------------
GMT  PH ATA
2236 02 31-00 RECORDER DFDR FAULT
2346 06 28-00 FUEL CTR TK PUMP 1 LO PR
2355 06 32-00 BRAKES BSCU CH 2 FAULT (2)
0049 08 32-00 BRAKES AUTO BRK FAULT
0049 09 52-00 DOOR L FWD EMER EXIT
0049 09 24-00 ELEC IDG 2 OIL LO PR
0049 09 34-00 NAV ILS 1 FAULT
0050 09 32-00 WHEEL N.W.STEER FAULT
0050 09 32-00 L/G LGCIU 2 FAULT
0050 09 26-11 AIR ENG1 BLEED ABNORM PR

FAILURE MESSAGES
----------------
GMT  ATA                                SOURCE      IDENTIFIERS
2236 31-33-55 DFDR                      FDIU
2240 34-12-34 ADR1                      EFCS 2      ECAM 1
                                                    ECAM 2
                                                    EFCS 1/AFS
2240 27-95-34 FWC1 :NO DATA FROM        ECAM 1      ECAM 2
              FCDC1
2240 28-42-34 FWC1 :NO DATA FROM        ECAM 1      ECAM 2
              FQI1A/1B
2251 36-11-00 PRESS REG-V 4001HA1       BMC 1
               OR SOLENOID 10HA1
2355 32-42-34 BSCU                      BSCU B
2355 32-42-34 BSCU                      BSCU A
0049 32-42-48 BRK NORM SERVOVALVE 15GG  BSCU A
0049 32-42-48 BRK NORM SERVOVALVE 17GG  BSCU A
1133 31-53-34 NO FWC 1 DATA             CFDS
1133 34-12-34 NO ADR 1 DATA             CFDS        ECAM 2
1133 31-33-34 NO FDIU DATA              CFDS
1134 23-73-34 NO CIDS 2 DATA (INTM)     CFDS
1134 27-51-34 NO SFCC 2 DATA (INTM)     CFDS
1134 34-36-31 FWC2 :NO DATA FROM        ECAM 2
              ILS1
1134 34-12-34 ATC-1:NO DATA FROM        ATC 1       TCAS
              ADIRU
1134 34-52-33 ATC1 (1SH1) / TCAS (1S    TCAS
1134 34-12-34 ATC-2:NO DATA FROM        ATC 2       EIS 1/EIS 3
              ADIRU
1134 34-36-31 DMC1: NO  ILS1  DATA      EIS 1
1134 34-36-31 FWC1 :NO DATA FROM        ECAM 2
              ILS1
1144 31-53-34 NO FWC 1 DATA             CFDS
1144 34-12-34 NO ADR 1 DATA             CFDS
1145 31-33-34 NO FDIU DATA              CFDS
1145 23-73-34 NO CIDS 2 DATA (1NTM)     CFDS
1145 34-12-34 DMC2: NO  ADC2  DATA      EIS 2       EIS 3
1145 34-43-00 DMC1: NO  TCAS  DATA      EIS 1       EIS 3
1145 22-83-34 DMC1: NO  FMC2  DATA      EIS 1
1146 32-31-71 AFS:LGCIU1-FAC1 CKT       AFS
1146 22-66-34 AFS:CHK FIDS-FAC1 CKT     AFS
1146 AS- -   EIS 2
1146 32-62-00 CHECK LGCIU-PHC3          PHC 3
              INTERFACE
1147 73-21-60 DMC3: NO  ECU1A DATA      EIS 3       EIS 1
```

APPENDIX H

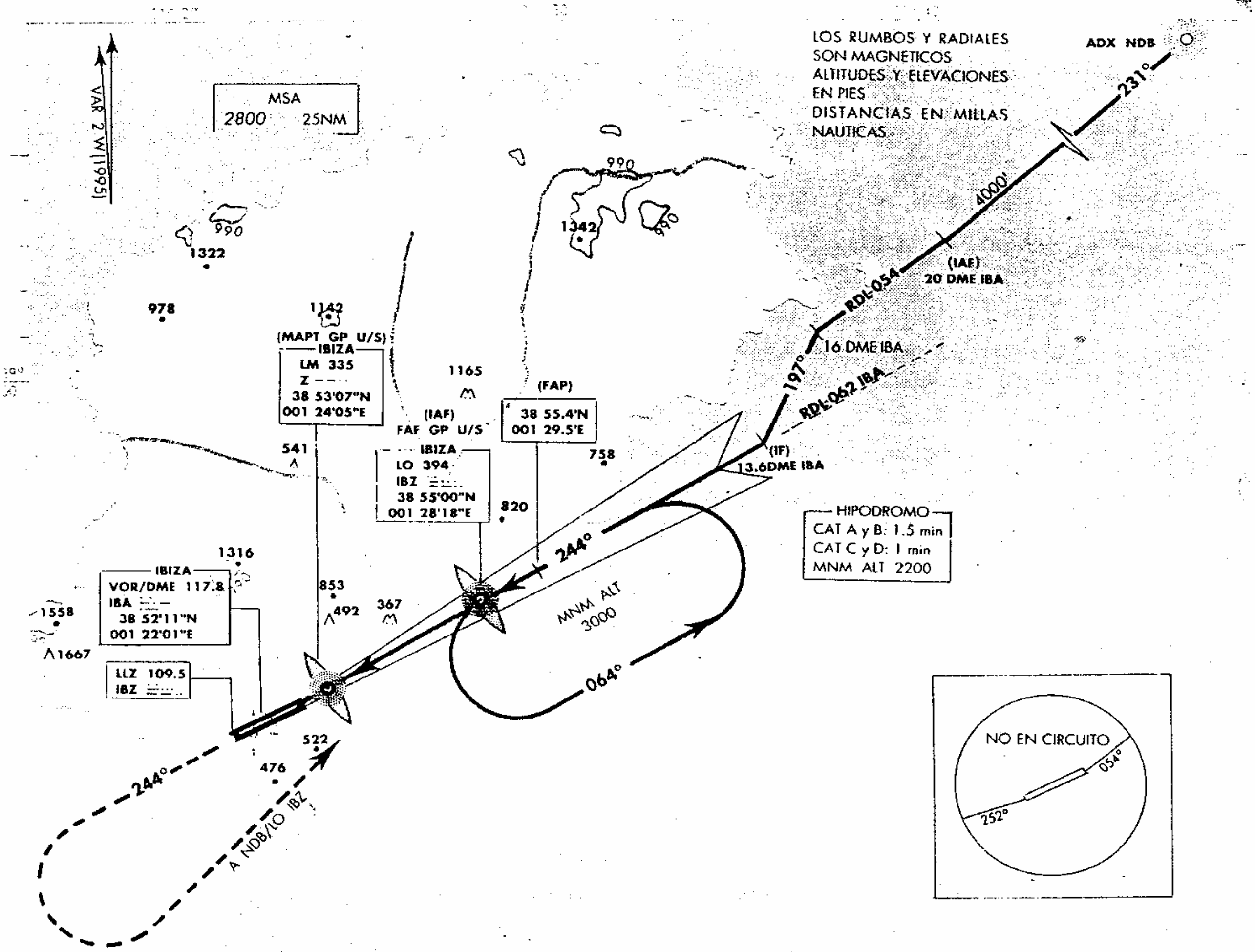
ILS Approach Chart to Ibiza Airport Runway 24.

CARTA DE APROXIMACION POR INSTRUMENTOS OACI

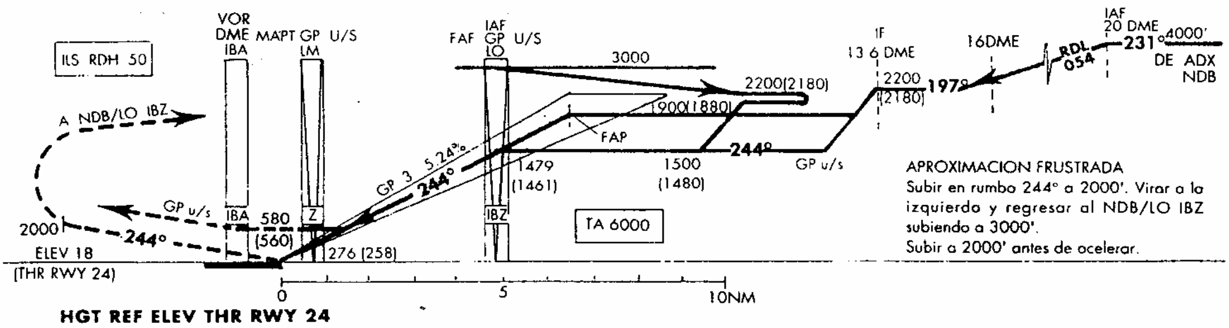
ELEV AD 23

TWR 118.5
APP 119.8
GMC 121.8

IBIZA ILS RWY 24



ESCALA 1:250 000



APROXIMACION FRUSTRADA
Subir en rumbo 244° a 2000'. Virar a la izquierda y regresar al NDB/LO IBZ subiendo a 3000'.
Subir a 2000' antes de ocelerar.

HGT REF ELEV THR RWY 24

OCA/H		A	B	C	D
STA	2.5%	249 (231)	261 (243)	269 (251)	280 (262)
	3%	198 (180)	210 (192)	218 (200)	249 (231)
	GP U/S	580 (560)			
En circuito (H) sobre 23		1090 (1070)	1090 (1070)	1190 (1170)	1450 (1430)

GS	kt	80	100	120	140	160	180
FAP-THR: 5.75NM	min:s	4:19	3.27	2:53	2:28	2.09	1:55
FAF-MAPT: 3.8NM	min:s	2.51	2.17	1:54	1:38	1:26	1:16
ROD: 5.65%	ft/min	425	531	637	743	849	955

ALT/HGT DME ( ) FNA

13 DME	12 DME	11DME	10 DME	9 DME	8 DME	7 DME	6 DME	5 DME	4 DME	3 DME	2 DME	1 DME

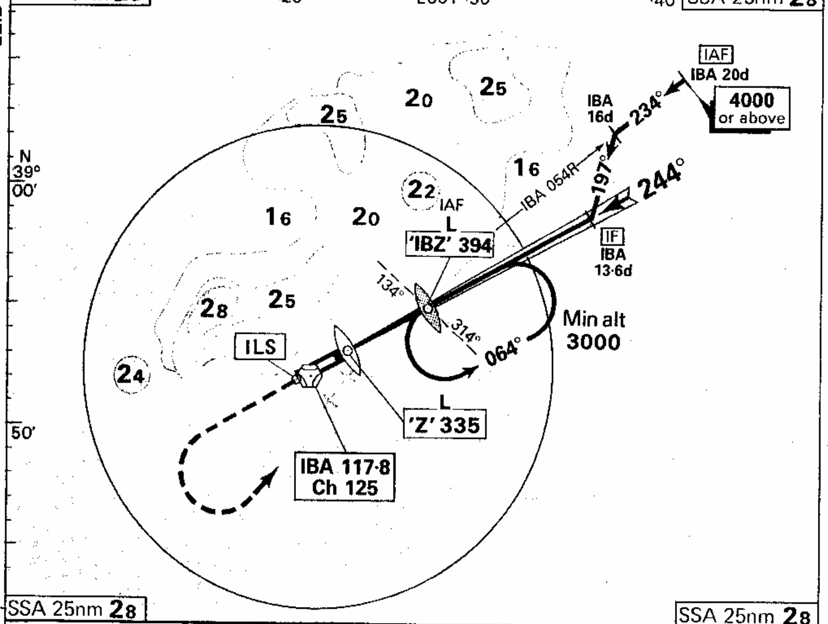
Elev 23	OCH See warnings box below

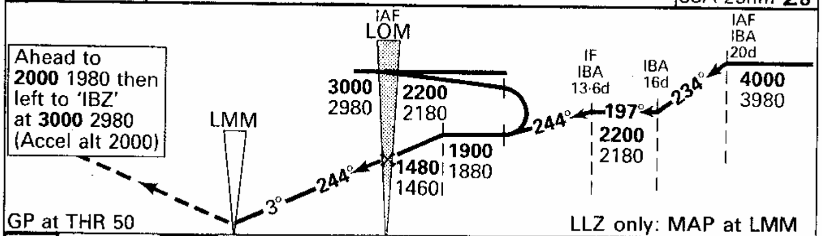
IBIZA

IBZ 109.5 **ILS 24**

IBIZA Approach 119·8	Tower 118·5	Ground 121·8	M1 LW EFF 28 APR 94

LEIB





Var 2°W	THR Elev 18/1mb	GP at LMM 280 260

	T.Lev ATC	T.Alt 6000
kt	fpm	OM
200	1060	–
180	950	THR
160	850	1:39
140	740	1:53
120	640	2:12
100	530	2:38
80	420	3:18

1. Max 250kt below FL 100.
2. Green crosses indicate ridges **530** 510 1.1nm & **480** 460 1.6nm south of R/W.
3. Racetrack Abm IBZ: fly outbound. Cat A B 1 min 30 sec. Cat C, D 1 min. Min alt 2200.
4. LLZ only Min alt at LOM **1500** 1480. Advisory figures in RH column compute at 3° angle of descent.
5. OCH ILS missed approach climb gradient 2.5% A231, B243, C251, D262. ILS missed approach climb gradient 3% A180, B192, C200, D231, LLZ560.

Rev: Procedure

IBA VOR/DME		
LOM	**1500**	1480
5d	**1310**	1290
4d	**990**	970
3d	**670**	650
2d	**360**	340

C1

APPENDIX I

Photographs

INDEX OF PHOTOGRAPHS

Nº 1

Nº 2

Nº 5

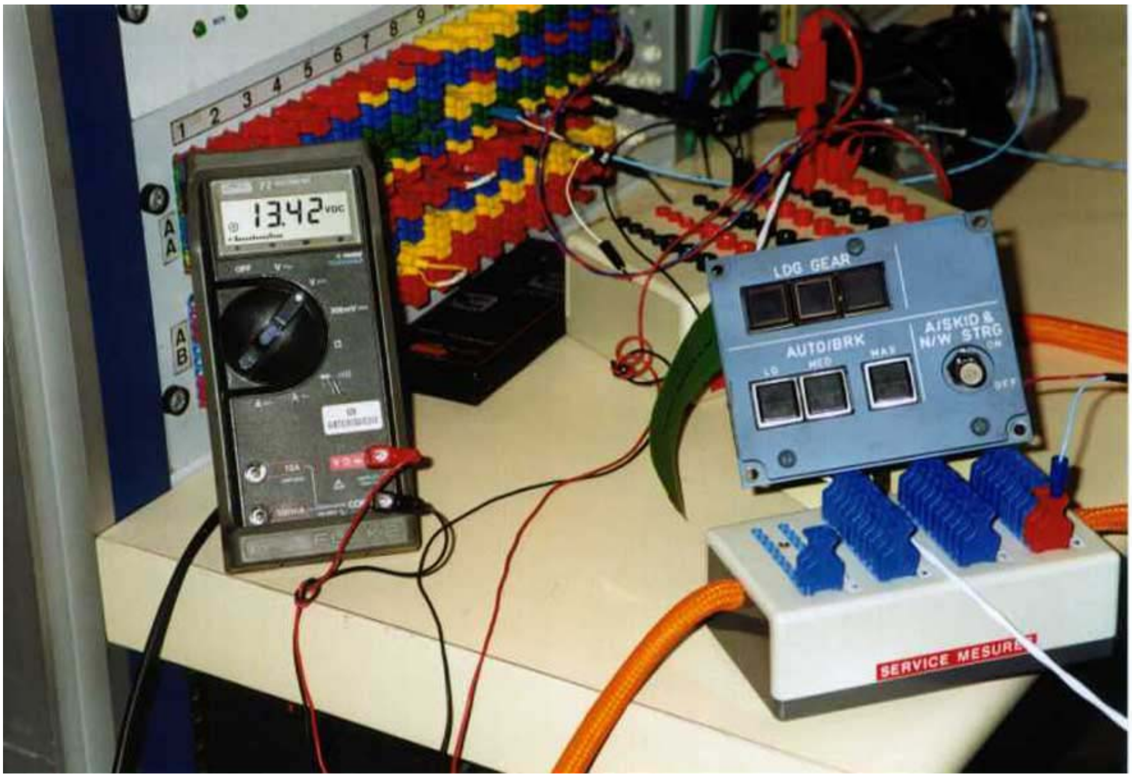
Nº 6

Nº 3

Nº 4

Nº 7

Nº 8



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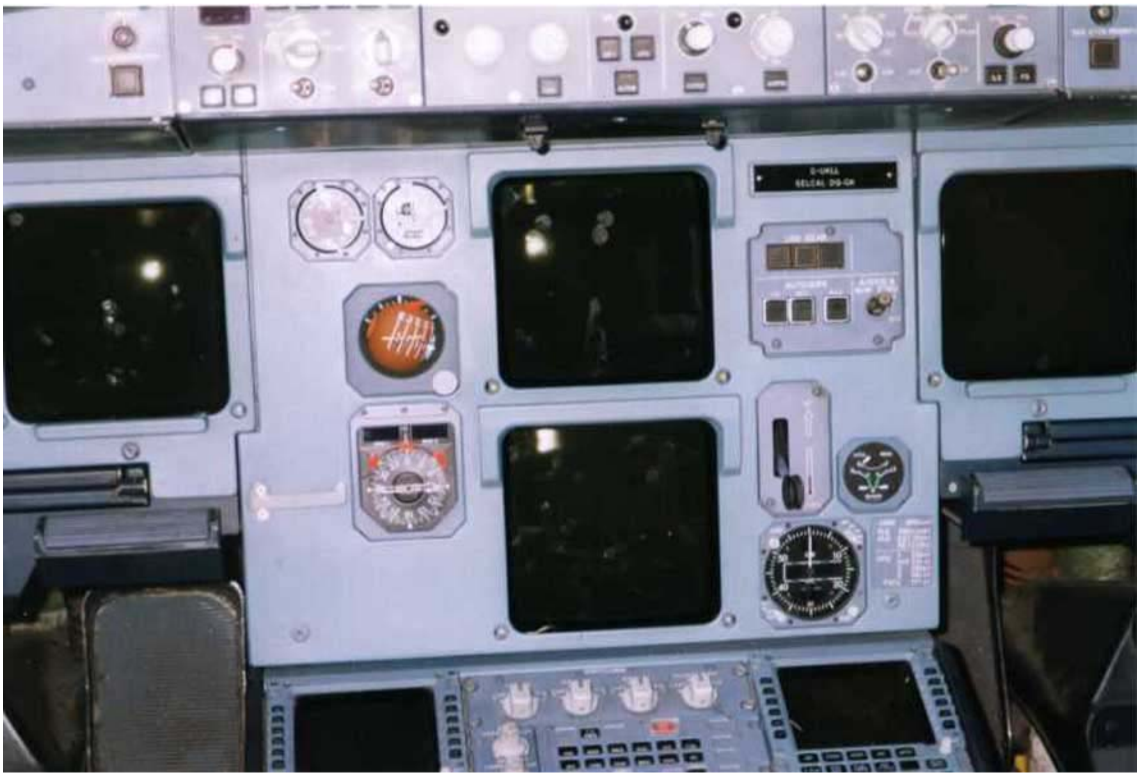

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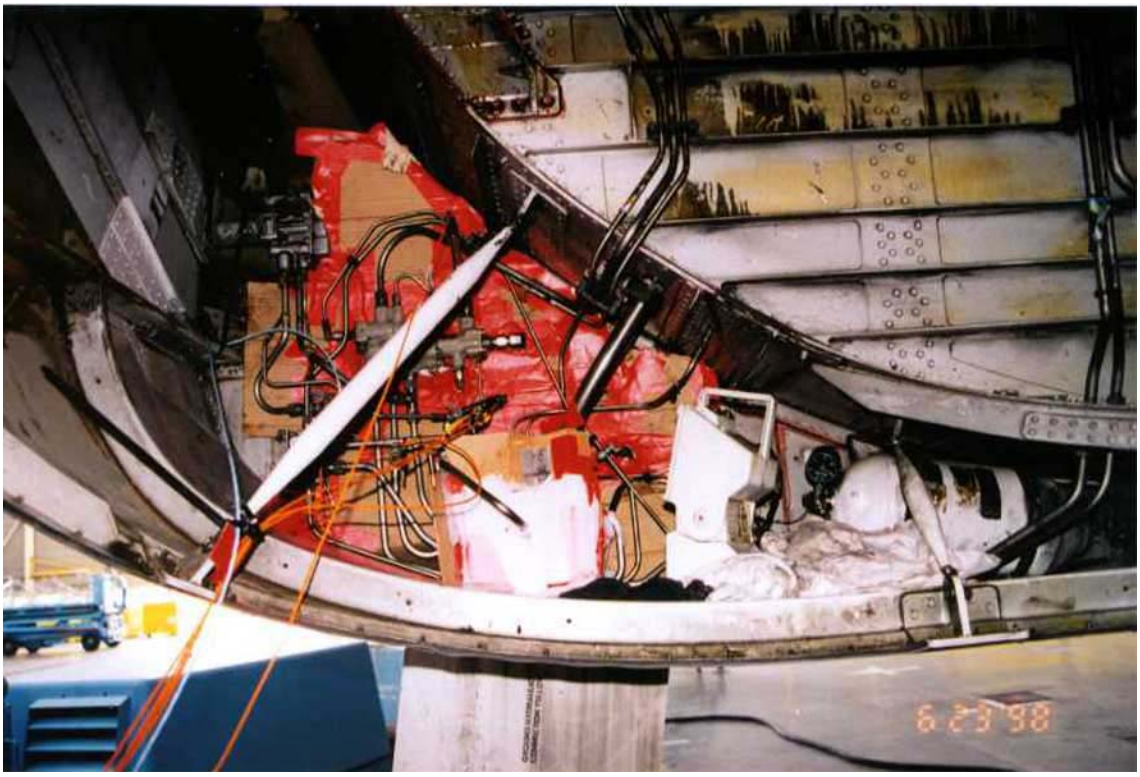

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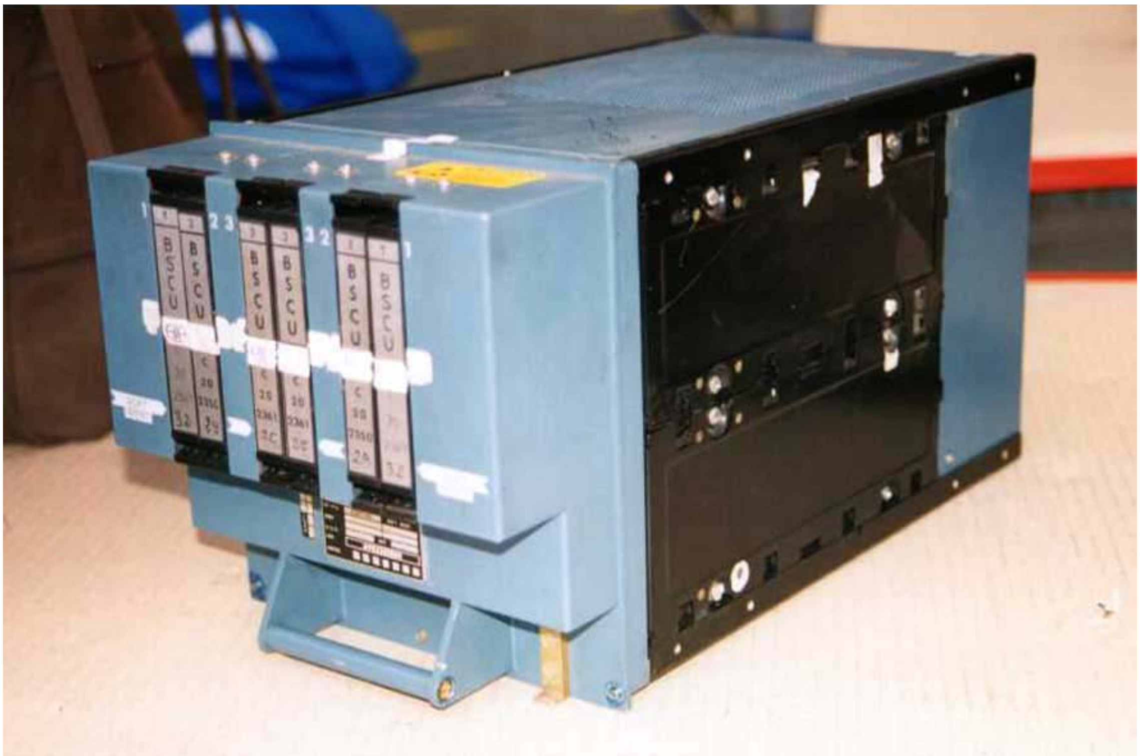

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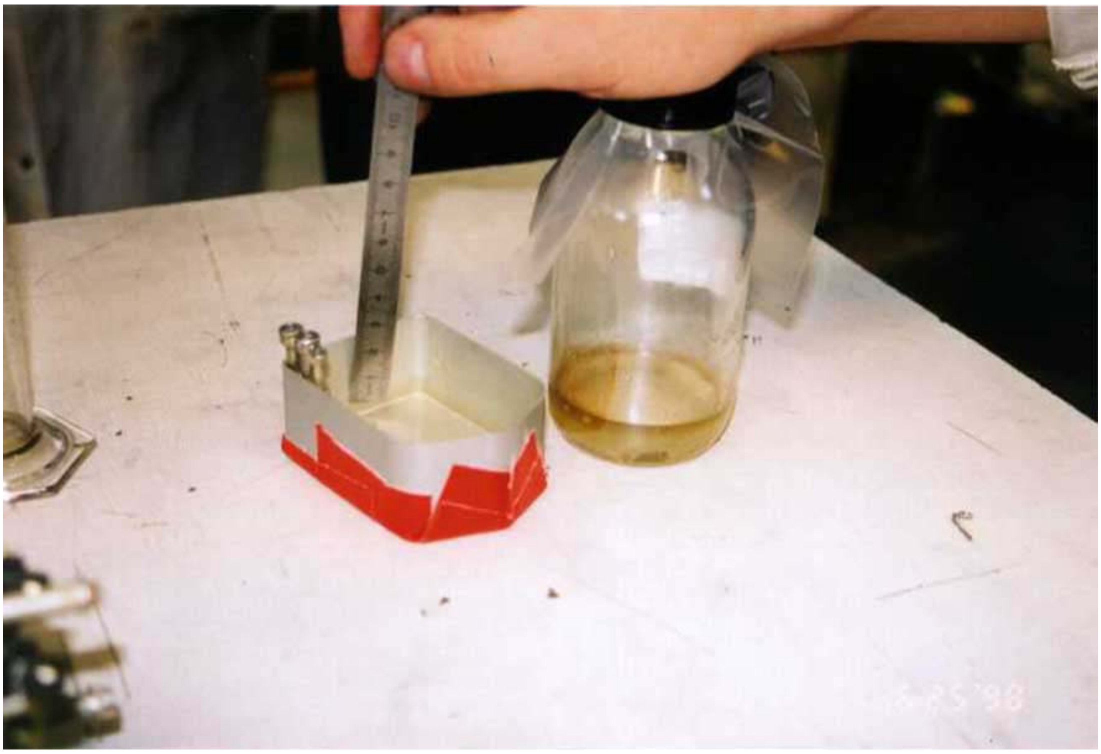

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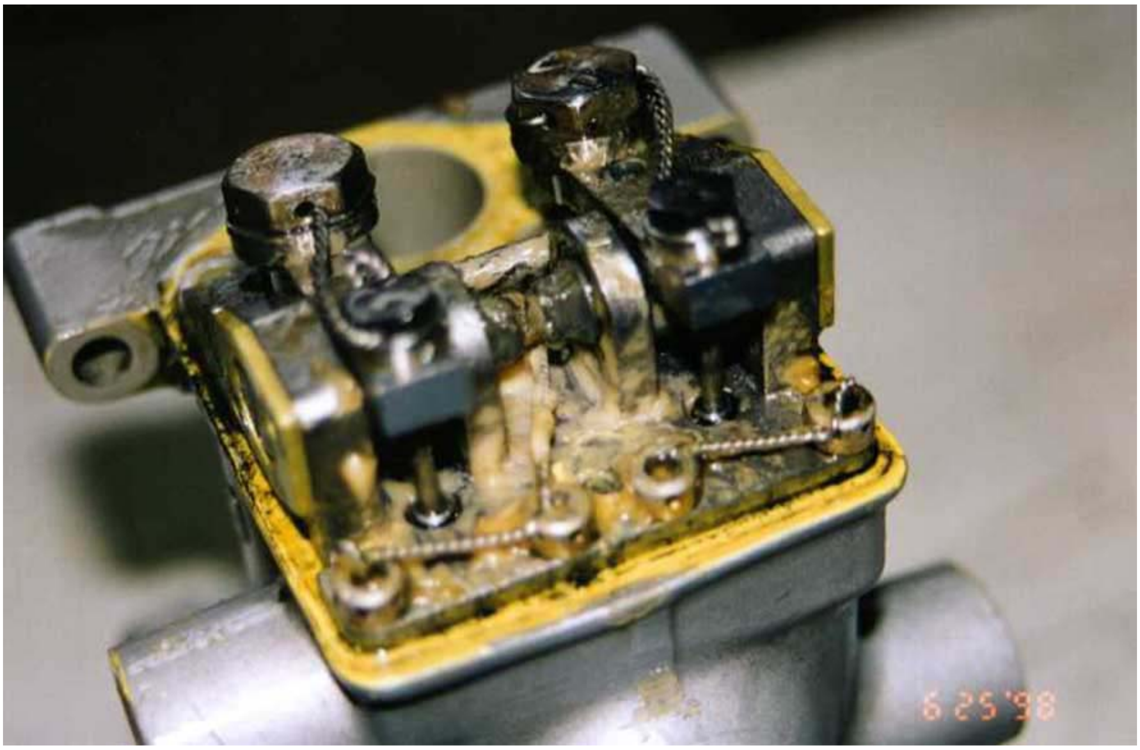

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