Runway departure, Incident of aircraft, Airbus A-340 registration EC-IDF, at Madrid-Barajas Airport (Madrid) on 7 September 2002

Micro-summary: **An Airbus A340 departs from the runway following braking difficulties.**

Event Date: **2002-09-07 at 1303 UTC**

Investigative Body: **Civil Aviation Accident and Incident Investigation Commission (CIAIAC), Spain**

Investigative Body's Web Site: **http://www.fomento.es**

Note: **Reprinted by kind permission of the CAAIIC.**

Cautions:

1. Accident reports can be and sometimes are revised. Be sure to consult the investigative agency for the latest version before basing anything significant on content (e.g., thesis, research, etc).

2. Readers are advised that each report is a glimpse of events at specific points in time. While broad themes permeate the causal events leading up to crashes, and we can learn from those, the specific regulatory and technological environments can and do change. ***Your company's flight operations manual is the final authority as to the safe operation of your aircraft!***

3. Reports may or may not represent reality. Many many non-scientific factors go into an investigation, including the magnitude of the event, the experience of the investigator, the political climate, relationship with the regulatory authority, technological and recovery capabilities, etc. It is recommended that the reader review all reports analytically. Even a "bad" report can be a very useful launching point for learning.

4. Contact us before reproducing or redistributing a report from this anthology. Individual countries have very differing views on copyright! We can advise you on the steps to follow.

CIAIAC
Comisión de Investigación
de Accidentes e Incidentes
de Aviación Civil

TECHNICAL REPORT IN-062/2002

Incident of aircraft Airbus A-340 registration EC-IDF, at Madrid-Barajas Airport (Madrid) on 7 September 2002

MINISTERIO
DE FOMENTO

Technical report

IN-062/2002

Incident of aircraft Airbus A-340 registration EC-IDF, at Madrid-Barajas Airport (Madrid) on 7 September 2002

MINISTERIO DE FOMENTO
SUBSECRETARÍA
COMISIÓN DE INVESTIGACIÓN DE ACCIDENTES E INCIDENTES DE AVIACIÓN CIVIL

Edita: Centro de Publicaciones
Secretaría General Técnica
Ministerio de Fomento ©

NIPO: 161-03-011-0
Depósito legal: M. 23.129-2003
Imprime: Centro de Publicaciones

Diseño cubierta: Carmen G. Ayala

COMISIÓN DE INVESTIGACIÓN DE ACCIDENTES E INCIDENTES DE AVIACIÓN CIVIL

Tel.: +34 91 597 89 60
Fax: +34 91 463 55 35

E-mail: ciaiac@mfom.es
http://www.mfom.es/ciaiac

C/ Fruela, 6
28011 Madrid (España)

Foreword

This report is a technical document that reflects the point of view of the Civil Aviation Accident and Incident Investigation Commission (CIAIAC) regarding the circumstances in which happened the event being investigated, with its causes and its consequences.

In accordance with the provisions of Law 21/2003 and Annex 13 to the Convention on International Civil Aviation, the investigation has exclusively a technical nature, without having been targeted at the declaration or assignment of blame or liability. The investigation has been carried out without having necessarily used legal evidence procedures and with no other basic aim than preventing future accidents.

Consequently, any use of this report for purposes other than that of preventing future accidents may lead to erroneous conclusions or interpretations.

This report has originally been issued in Spanish language. This English translation is provided for information purposes only.

Table of contents

Abbreviations

00 °C	Degrees Celsius
00° 00′ 00′	Degrees, minutes and seconds
AENA	«Aeropuertos Españoles y Navegación Aérea», provider of ATC and airport services
AGL	Above Ground Level
AMM	Aircraft Maintenance Manual
ATC	Air Traffic Control
bar	Bar, unit of pressure
BDDV	Brake Distribution Dual Valve
BITE	Built-in test
BSCU	Brake & Steering Control Unit
CMM	Component Maintenance Manual (i.e. of a master cylinder, valve, etc.)
CMS	Central Maintenance System
CVR	Cockpit Voice Recorder
DFDR	Digital Flight Data Recorder
DH	Decision Height
DME	Distance Measuring Equipment
E	East
ECAM	Engine and Crew Alerting Monitoring
FCOM	Flight Crew Operating Manual
FOT	Flight Operations Telex, communication of Airbus to the operators to inform on operational issues
ft	Feet
g	Gravity acceleration
GPWS	Ground Proximity Warning System
h: min: sec	Hours, minutes, seconds
hPa	Hectopascal
IAS	Indicated airspeed
IFR	Instrument Flight Rules
KCAS	Knots of calibrated airspeed
kt	Knots
lbs	Pounds
LRU	Line Replaceable Unit
m	Meter
mb	Milibar
METAR	Meteorological report
MHz	Megahertzs
MLG	Main landing gear (there are three legs in the MLG of the A-340: left, centre and right)
N/A	Not affected
NLG	Nose landing gear
NM	Nautical Mile
OIT	Operators Information Telex
P/N	Part Number
S/N	Serial Number
SOP	Standard Operating Procedures, prepared by the manufacturer of the aircraft
SSCVR	Solid State Cockpit Voice Recorder
TFU	Technical Follow-up (communication on in-service difficulties issued by Airbus)
TSM	Trouble Shooting Manual
TWR	ATC Control Tower
UTC	Universal Time Coordinated

Synopsis

On 7 September 2002, at 13:03:27 h, the left and right legs of the main landing gear of the aircraft Airbus A-340 registration EC-IDF touched down onto runway 33 of Madrid-Barajas Airport. At that moment, there was a residual pressure of 800 psi on the alternate hydraulic system of the brakes of the left main landing gear leg. The crew, that had already detected the presence of that residual pressure at 12:58:02 h when the WHEEL page of the ECAM was deployed before lowering the landing gear, had decided to land with the antiskid system disconnected, and had voluntarily moved the «antiskid & nose wheel steering» switch to the OFF position.

At the beginning of the landing roll, the pilot in command applied reverse, did not press the brake pedals and used right rudder with the intend of keeping the aircraft aligned with the runway axis. At a point between 240 m and 900 m beyond the threshold of runway 33, the four wheels of the left main landing gear leg burst, and the aircraft deviated initially to the right of the runway axis and then to the left until both crew members applied full right brake, and the pressure reached 2500 psi on the brakes of the four right wheels that locked and burst.

Finally, the aircraft came to a stop with the left main landing gear leg at 5m from the left end of the asphalt area of runway 33, and at 146 m before the axis of the taxiway J-1, with the fuselage rotated around 10° to the left of the axis of runway 33. The rims of wheels 1, 2, 4, 5 and 6 suffered heavy damage, as well as the brakes 1, 5 and 6, due to the drag with the runway surface. There was a fire that affected all the wheels of the right and left legs of the landing gear, and it was quickly controlled by the fire fighters of the airport.

Runway 33 remained closed during approximately 6 h and 15 min and there were no personal damages.

The investigation determined that the cause of the residual pressure in flight was the left master cylinder P/N C24592020 S/N H2121, which had a length and a dead band longer than specified.

It is considered that the cause of this incident was the fact that, as a consequence of the appearance of residual pressure in flight in the left brakes, due to the fact that the left master cylinder P/N C 24592020, S/N H2121 was defective, and due to the lack of a procedure to be applied in that case, the crew voluntarily disconnected the antiskid system when the residual pressure was still present, which produced the burst of the left tires at touchdown.

The following factors could have prevented the incident:

— The existence in the Operations Manual of instructions to be followed in the case of residual pressure being observed in flight.
— The knowledge by the affected flight crew of similar cases that had been reported as complaints during June 2002.
— A more comprehensive analysis of the previous squawks of residual pressure.
— A more detailed training on the brake system during the type rating courses.

1. FACTUAL INFORMATION

1.1. History of the flight

1.1.1. *Flight Madrid-Tenerife Norte*

The aircraft took off from Madrid-Barajas Airport on 7 September 2002, at 06:56 h UTC[1], with 263 people on board (12 crew members and 251 passengers). The destination was the Airport of Tenerife-Norte. The takeoff weight was 201033 kg and the landing weight in Tenerife was 184333 kg. The maximum landing weight is 190000 kg.

It was the first flight of the aircraft since 28-7-2002, because it had been repaired after a bird strike on the nose area that happened on that date.

The flight was normal and, during the approach to runway 12 in Tenerife-Norte, when the landing gear was lowered at 9:19:24 h, the copilot noticed that in the wheel page of the ECAM there were indications of residual pressure in the brakes of the left MLG. The 24 bars that represent the brakes of the 4 wheels of that landing gear were lit in amber colour.

The crew considered that this indication, which is not associated to any caution message, could be spurious, and for that reason they decided to land without additional measures.

The aircraft continued the approach with the antiskid system connected and with the autobrake systems disconnected. After switching off the autopilot, the copilot was the PF during the approach and landing in manual mode with the autothrust connected.

After touching down, according to his statement, the copilot noted that the aircraft started deviating to the left of the runway, and therefore applied progressively right rudder until reaching full deflexion. Then he applied brakes, initially right toe brake and then both brakes, always steeping more the right pedal, until the aircraft, which initially had approached at around 8 m from the left side of the runway 12, deviated towards the right and finally came to a stop with its centre of gravity separated around 5 m to the right of the runway axis.

The DFDR data show that at the moment of the landing there was a pressure of 900 psi in the left alternate brake system. After the left and right legs touched the ground at 9:21:43 h and the spoilers started to deploy, the brake pedals were not pressed, and therefore the alternate system remained active and the 900 psi of pressure were trans-

* All the times used in this report are UTC, except where specifically noted. It is necessary to add two hours to have the local time in Madrid-Barajas Airport, and one hour to have the local time in Tenerife-Norte Airport.

mitted to the wheels. The copilot used more and more right rudder to counteract the increasing tendency to veer to the left as the airspeed was decaying. Within 9:21:50 h and 9:22:03 there were small movements of the right brake pedal, of around 8° (the following angle values correspond to the pedal potentiometer; the maximum deflexion of the pedal corresponds to a pedal potentiometer position of 68.80°; the maximum physical pedal deflexion is 14°11') that were not enough to send pressure to the normal brake system until 9:22:03 h, at which moment both pedals were pressed (52° the right pedal and 26° the left pedal), the normal system was pressurized and the residual pressure of the alternate system was released. From that moment on, the aircraft behaviour regarding braking was normal.

The tower said to the crew at 9:27:10 h that they could vacate the runway at their discretion and the crew of EC-IDF answered that they had a brake problem and they would call back when ready to leave the runway.

The tower advised another traffic that was in short final to be ready to go around because the runway was occupied.

The crew of EC-IDF switched off and then on the BSCU. The residual pressure had disappeared. At 9:27:43 h, they told the tower controller that they were going to leave the runway «through the first on the left» and started a taxi by their own means until they confirmed «runway vacated» at 9:29:25 h and asked for the possibility to stay at that point of the taxiway for a few minutes. The tower requested them to move a little more forward because they still protruded a little bit over the runway.

The aircraft moved as requested and at 9:29:52 h they said that they were proceeding to the parking apron. The tower asked whether they needed towing or were able to move by their own means, and also whether they needed further help.

The crew answered that they would taxi by their own means. At those moments, they were noting that the temperature of the four brakes of the left MLG was increasing a lot, and called their ground operations department to advise that maybe a maintenance action was going to be needed. Operations asked whether fire fighting services were going to be needed and the pilot in command answered in the positive and requested that nobody approached the aircraft.

At 9:33:35 h, the flight that had landed after EC-IDF called tower to advise that they were seeing smoke coming out from the «left rear wheel» of that aircraft.

The crew of EC-IDF acknowledged the information and thanked for it. The temperature of the wheels of the left MLG had continued increasing until an ECAM caution was triggered. The aircraft contacted ground movement frequency at 9:35:36 h and the controller asked whether they needed that the fire fighters applied water or preferred the

wheels to be cooled alone. The crew answered they were going to check with the maintenance personnel and finally rejected the offer to apply water.

1.1.2. *Stop in Tenerife Norte*

CWhen the aircraft reached the parking, chocks were put in the wheels and the brakes were cooled using two fans provided by the line maintenance of the operator and another provided by the fire fighters that were around the aircraft. The passengers disembarked the aircraft in a normal way.

According to his statement, the pilot in command informed the ground maintenance personnel about the incidence during the landing and it was commented that the problem would be consulted with the operator's main base in Madrid.

According to their statement, the maintenance personnel entered the cockpit and saw the high brake temperature caution and observed in the post-flight report that there had been a caution of «Brakes residual braking». They tried to test the BSCU 1 and 2 but they were unable to do that.

The information gathered shows that while the maintenance personnel were trying to locate technical advice in the Madrid base, the passenger boarding of next flight Tenerife-Madrid started, with the same flight crew that had flown the previous leg.

Some information was interchanged with the pilot in command, who understood that the maintenance personnel had no inconvenience for the starting of the flight back to Madrid. However, these personnel were still considering the possibility of lifting the left MLG to check the free movement of the wheels, although in the end this action was not carried out because during the previous taxi to the apron the wheels seemed to have behaved correctly.

Once the boarding ended, a person from maintenance Madrid called the line maintenance Tenerife and was informed about the situation. Since in the ECAM screen there was no caution, and the brake temperature had fallen within normal limits, this conversation did not produce further maintenance actions and therefore the doors were closed and the aircraft started the taxi for takeoff.

The maintenance personnel advised the pilot in command to watch the temperature during the taxi just in case a new cooling was needed. The aircraft taxied normally, and the pilot in command informed that after the takeoff he would leave the landing gear down for some minutes to further cool it.

In the aircraft logbook the crew did not write any squawk after the landing in Tenerife. The maintenance personnel wrote that the normal «transit» line check was comple-

ted, but they did not report any of the actions carried out on the brake system. Neither in that flight nor in next flight (Tenerife-Madrid where the incident happened) was the aircraft acceptance form signed by the pilot in command.

1.1.3. *Flight Tenerife Norte-Madrid*

The aircraft, with the flight identifier IB-0959, took off around 10:55 h from Tenerife, after a taxi of 5 min since the moment of chocks off during which the general behaviour of the aircraft was checked and it was confirmed that no new cautions appeared.

The takeoff was normal, with a weight of 173404 kg, compared with the maximum takeoff weight of 275000 kg. There were 247 passengers and 12 crew members on board.

The brake temperatures were still slightly high, and therefore the crew left the landing gear down for several minutes after lift-off.

The flight progressed normally. The crew did not show excessive concern with respect to the reappearance of the failure in Madrid.

At 12:58:02 h, with the landing gear still up, the copilot called the WHEEL page of the ECAM and they saw again the there was residual pressure in the brakes of the left MLG, because the bars that represented the brakes appeared again in amber colour. The crew disconnected and then connected the BSCU but the amber bars did not disappear.

At 12:58:38 h landing gear down was selected, the system started its normal self-checks and the residual pressure disappeared momentarily but almost immediately appeared again. The crew again disconnected during 24 s and then connected the BSCU, although this action, not permitted by the operational procedures when the landing gear is extended, did not succeed in eliminating the residual pressure indication.

Since the moment they noticed there was residual pressure in the left leg, both pilots were commenting the possible actions to be taken. It was discussed the possibility of discontinuing the approach, and it was commented that the only solution would be to disconnect the antiskid because in that case the system was not going to brake by itself, and, therefore, to lock the wheels.

Finally, the copilot disconnected the antiskid system and nose wheel steering switch after asking the pilot in command for conformity.

The aircraft continued its approach to runway 33 of Madrid-Barajas Airport with the pilot in command acting as PF. The aircraft configuration was flaps down and landing

gear down, without autopilot but with autothrust connected, and with the antiskid and the autobrake off. The spoilers had not been armed during the approach.

The pilot in command, taking into account the low weight and the length of the runway in Barajas, had decided to touchdown as soon as possible onto the runway and to apply thrust reverse, without touching the brakes as long as it was not indispensable. There was no communication to the passengers or cabin crew, and the ATC was not informed that there could be some problem with the aircraft.

The approach continued and the pilot in command recalled after the incident that the aircraft touched the ground over the numbers of runway 33. The left and right MLG touched down around 13:03:27 h and the reversers were selected three seconds afterwards. The central MLG and the NLG touched down at around 13:03:32 h. At the moment the main legs touched down, the spoilers did not deploy, because they were not armed.

When the reversers were deployed, the spoilers deployed in accordance with the system design, which always deploys them even when they were not armed during the approach.

At the first moment they touched down the wheels of the left leg were braked with around 800 psi of residual pressure. The pilot in command, without pressing the brake pedals, applied progressively more and more right rudder to try to keep the aircraft aligned with the runway axis.

At 13:03:45 h the right brake pedal was pressed up to the limit, which made the pressure to increase up to around 2500 PSI and the wheels of the right MLG burst in that area.

Finally the aircraft came to a stop at 13:04:01 h in such a manner that the left leg remained at around 146 m before the axis of the taxiway J-1 (the first exit after the intersection of runways 33 and 36L) and at around 5 m from the end of the paved runway shoulder, that is, it has crossed the line of the lateral runway edge lights. The longitudinal axis of the aircraft had turned around 10 degrees to the left with respect to the axis of runway 33 and, therefore, the nose MLG leg also remained at approximately 5 m away from the lateral end of the paved runway shoulder.

1.1.4. *Actions taken after landing and evacuation of the passengers*

After the aircraft came to a stop, the crew informed the tower that they had a problem with the brakes and that they were going to remain on the runway. The ATC commanded the next aircraft that was approaching to runway 33 to go around and called the fire fighters.

At around 13:04:32 h, that is, approximately 30 s after the aircraft came to a stop, the aircraft that was going around informed by radio that the EC-IDF had fire on the wheels. The air traffic controller answered that with so much smoke she could not really see what had happened. Then she commanded another aircraft to go around.

When they heard the information about fire on their wheels, the crew of EC-IDF decided to shut down the engines. For several minutes, they were evaluating the possibility of ordering an emergency evacuation of the airplane. After 3 min and 8 s since the aircraft stopped, the flight crew addressed the passengers to advise them to remain seated without using the mobile telephones.

At 13:06:22 h the crew called by radio their Operations Department to request assistance to transport the passengers and to tow the aircraft. They called then tower to ask for confirmation that only smoke was present in the wheels and on their side informed the air traffic controller that the fire fighters were already around the aircraft. The tower answered saying that it was confirmed that the fire was extinguished and asked for the possibility of the aircraft to taxi to leave the runway.

When she received a negative answer from the flight crew, that suspected that they had all the wheels burst, the air traffic controller commanded other aircraft to go around while in the airport several services started to coordinate and communications were held with approach control services after the local alarm was activated. The surface of runway 36R was inspected and was open for arrival traffic around 13:16 h, while runway 36L was still active for takeoffs.

In the meanwhile, inside the aircraft, the crew said to the passengers that there had been a problem with the brakes and that coaches would arrive soon to take them from the aircraft to the terminal. This address took place after a request of the pilot in command 4 min and 8 s (13:08:09 h) after the aircraft stopped.

At 13:24 h the passengers started coming out the aircraft using door 1R and a stairway provided by the ground handling personnel. When all the passengers had left the aircraft, the crew also evacuated it. The passengers were taken to the terminal by shuttle coaches.

The maintenance personnel of the operator replaced all the wheels of the left and right MLG and around 18:25 h the aircraft was towed towards the maintenance hangars. The area was cleaned and runway 33 and its lighting system were inspected. At 19:21 h runway 33 was again open for arrival traffic.

1.2. Injuries to persons

Injuries	Fatal	Serious	Minor/none
Crew			12
Passengers			251
Others			

1.3. Damage to aircraft

The eight wheels of the left and right MLG burst during the landing roll, and the wheel rims dragged over the runway surface. The lower part of the four left brake assemblies was totally disintegrated as a consequence of the contact with the ground. The eight wheels and their brake assemblies were replaced.

After the incident, following a troubleshooting procedure prepared by Airbus (see 1.16) and before any further flight, the left brake master cylinder P/N C24592020, S/N H2121, was also replaced.

The left leg assembly of the MLG had eventually to be completely replaced, because of the loads suffered during the landing roll once the wheels had burst. There was fire on all the wheels of the left and right MLG, but no other part of the aircraft was affected by that fire.

1.4. Other damage

After a visual inspection, it was determined that there was no appreciable damage to the paved surface of runway 33 of Barajas airport. Therefore, there was no other damage in addition to those to the aircraft.

1.5. Personnel information

1.5.1. *Pilot in command*

Age:	59 years old
Nationality:	Spanish
Title:	Airline Transport Pilot
Licence:	Valid since 21-1-2002 until 21-1-2007
Type rating:	Pilot in command A-340. He had also flown DC-9, B-727 and A-300
Total flight time:	10439 h
Hours in the type A-340:	3250 h
Hours in the last 90 day:	175 h
Latest simulator check:	8-4-2002

He attended the A-340 pilot in command type rating course in Iberia within 12-5-1997 and 13-7-1997, with a flight instructor that got his rating in Airbus/Miami. Afterwards, he attended the following two-day recurrent training courses also in Iberia:

> January 1998; July 1998; March 1999; November 1999; June 2000; November 2000; January 2001; July 2001.

On 8 April 2002 he renewed the type rating after some sick leave.

The pilot in command had flown last time on 29 August before initiating a new activity period on 7 September at approximately 5:50 h.

1.5.2. *Copilot*

Age:	33 years old
Nationality:	Spanish
Title:	Airline Transport Pilot
Licence:	Valid until 29-10-2006
Type rating:	Copilot A-340. He had also flown MD-87
Total flight time:	2310 h
Hours in the type A-340:	1420 h

Hours last 90 days:	210 h
Latest simulator check:	27-10-2001

He attended the A-340 type rating course in Iberia within 23-6-2000 and 17-8-2000, with a flight instructor that got his rating in Airbus/Miami. Afterwards, he attended the following two-day recurrent training courses also in Iberia:

July 2001; October 2001; May 2002.

The copilot had flown last time on 6 September, and had had 16 h and 30 min of rest before initiating a new activity period on 7 September approximately at 5:50 h.

1.5.3. *Type rating training*

The Training Manual of the operator was reviewed and it was found that the initial type rating course included 6 h of ground instruction devoted specifically to electrical, hydraulic, landing gear and APU systems. Later on, the second session in flight simulator, which had an estimated time of completion of four hours, was devoted to ECAM, actions after failures, and hydraulic and electrical systems with generated failures and the corresponding ECAM actions. The operator stated that they used as a base the Airbus recommended training syllabus and procedures as included in the Airbus «A340 Flight Crew Training Manual», from which they provided the investigation with the relevant pages of the «Standard Course». Additionally, they stated that their refreshment courses covered all the systems of the aircraft every two years, i.e. one year below the JAA requirement of three years to complete the review of all the systems.

After the incident, the manufacturer reviewed their syllabus for A-340 type rating in the part relative to brakes and they concluded that their recommended syllabus was adequate and no change was needed. No information was gathered regarding the details of the residual braking training recommended or provided.

1.6. Aircraft information

1.6.1. *Airframe*

Make:	Airbus
Model:	A-340-313
Serial number:	MSN 474

Registration:	EC-IDF
Year of manufacture:	2002
M.T.O.W.:	275000 kg
Operator:	Iberia L.A.E.
Total flight time:	960 FH
Total flight cycles:	133 FC

1.6.2. *Description of the brake system of the A-340-313*

According to the description of the Operations Manual prepared by the operator of the aircraft, the A-340 has brakes in the wheels of the right and left MLG (the central leg of the MLG does not have brakes) that may be applied by any of the two independent brake systems (normal system, or green system, and alternate system, or blue system). There are also autobrake and antiskid.

The brake commands may come from the pilot, when the brake pedals are pressed, or from the autobrake, with a deceleration rate previously selected by the crew. When in normal mode, all those commands are controlled by the Brake System Control Unit (BSCU) that has two channels. The alternate (blue) system is hydromechanical.

This BSCU also checks the residual pressure and the temperature of the brakes and provides information on the speed of the wheels to other systems of the aircraft.

In flight, only the alternate system is pressurized and available. During landing, the brakes revert to the normal system at the moment the brake pedals are pressed or at the moment of touchdown if the autobrake system is armed.

When the normal system pressurizes and is active, the feed of pressure to the alternate system is automatically cancelled. The brakes also momentarily revert to the normal system in flight when the landing gear is lowered, while several auto tests are being performed in the brake system.

1.6.2.1. Antiskid system

The antiskid system provides a maximum braking efficiency maintaining the speed of the wheels at the limit of slipping. The antiskid function is automatically disconnected on ground when the speed is below 10 kt. There is a switch (A/SKID & N/W STRG) in the cockpit with to positions (ON/OFF) that allows the manual connection and disconnection of the antiskid and the nose wheel steering functions at the same time.

The antiskid system never increases the pressure by itself, but simply releases or maintains the pressure applied by other parts of the system (the pedals or the autobrake).

1.6.2.2. Autobrake system

This system reduces the delay in the braking action in the event of an acceleration-stop to improve the performances and establishes and maintains a deceleration rate during landing to improve the comfort and reduce the workload of the flight crew.

The system may be armed before the landing pushing the switches LO, MED or MAX (braking rate low, medium or maximum) under certain conditions, including that the antiskid system must be electrically energized.

During the landing roll the autobrake action starts with the command to extend the spoilers.

The normal procedures of the operator (Operations Manual A340, 2.01.63, 4-12-2000) indicate that in final the autobrake may be selected at LO or ME («if required») and then add: «In the event of crosswind, contaminated or short runway, or under low visibility conditions, select LO or MED. In a dry runway of normal length, normally the use of autobrake is not necessary».

However, the procedures recommended by the manufacturer of the aircraft indicate:

> «Use of the autobrake is recommended.
> Use of MAX mode is not recommended at landing.
> On short or contaminated runways, use MED mode.
> On long and dry runways, LO mode is recommended.
> Note: If, on very long runways, the pilot anticipates that braking will not be needed, use of the autobrake is unnecessary.
> Press the appropriate pushbutton, according to runway length and condition, and check that the related ON light comes on.«

1.6.2.3. Brake modes

There are four modes of operation of the brakes:

A) Normal braking: when there is hydraulic pressure of the first system, called green hydraulic pressure and the switch A/SKID & N/W STRG is in ON, among other conditions. The control is electrical through the BSCU, and the braking command is provided with the pedals or automatically by the autobrake (on ground) or when

the landing gear lever is moved to «UP» (in flight). There is no indication to the crew of the hydraulic pressure applied to the brakes.

B) Alternate braking with antiskid: when the normal or green hydraulic pressure is not enough, and the switch A/SKID & N/W STRG is in the ON position, there is an automatic selection of the blue or second hydraulic system, and the alternate braking system is available. In this case, the control is achieved through the pedals through an auxiliary low pressure circuit that actions the DUAL valve. The BSCU continues controlling the antiskid system. The pressure sent to the left and right brakes, and the pressure of the accumulator, appear in a triple indicator located in the centre of the instrument panel (see Figure 1).

It is important to note that the pressure transducer to the triple indicator and to the ECAM indication is the same. For this reason, spurious indication of residual pressure may occur in the ECAM and in the triple indicator at the same time, and those transducers were mentioned in the TFU (see 1.6.3) as a common cause of the false residual pressure indication.

C) Alternate braking without antiskid: If the switch A/SKID & N/W STRG is manually moved to the OFF position, or there is a failure in the electrical supply or failure of the BSCU, or when there is a low hydraulic pressure in both the green and blue systems, the antiskid system is disconnected. The control is achieved through the pedals, that actuate the DUAL valve, while the servo valves of the alternate system are fully open and all the pressure commanded by the pedals reach

Figure 1. View of the triple indicator of pressure. The landing gear is down, but the antiskid switch is in OFF. Therefore, the vertical bars that represent the brakes of every wheel do not appear in the WHEEL page of the ECAM screen

directly the brakes, and therefore the pilot has to regulate the pressure with the pedals with reference to the triple indicator to avoid the lock and burst of the wheels.

D) Parking brake: In this mode the brake receives the hydraulic pressure of the blue system or of the accumulator through the DUAL valve. This brake may be used in emergency.

1.6.2.4. Indications, warnings and cautions

In addition to the triple indicator mentioned above, the WHEEL page of the ECAM («Engine indication and alert monitoring») presents a schematic indication of the eight wheels of the MLG that have brakes (four on the left leg and four on the right leg) together with additional information on the brake system, including the status of the antiskid system, of the autobrake system (AUTO BRK), rate of autobrake selected (MED), and brake temperature (F in the attached Figure 2) of every wheel (numbered as shown in item D in the attached figure).

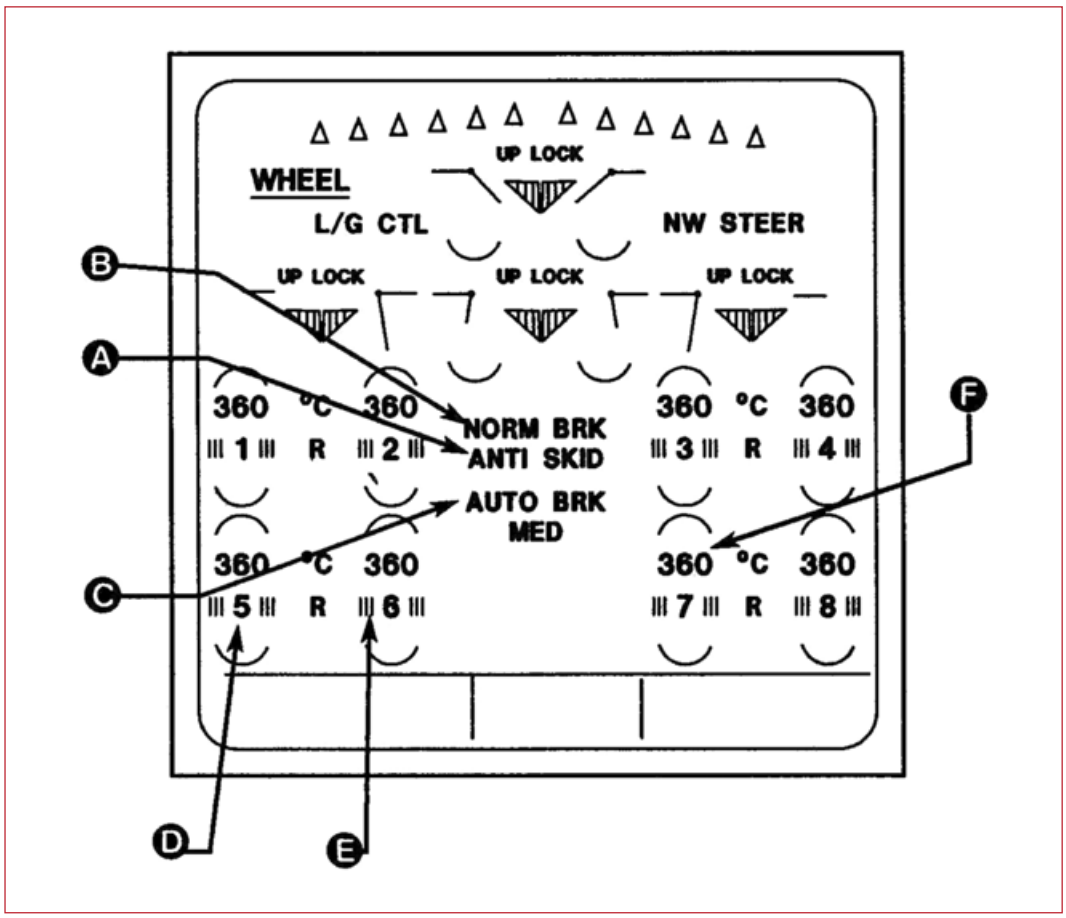


Figure 2. Wheel page of the ECAM

On the other hand, in both sides of each wheel three vertical bars appear (item E in the Figure 2) that represent the brakes of that side of the wheel. They appear in green colour in flight, when the landing gear is down and the antiskid is operative, and on ground when the brakes are released and the antiskid is active. They appear in amber colour in the event that there is residual pressure or if there is a failure in the release of the brakes.

The indication R («release») always appears in white colour.

There is residual pressure whenever, with the brakes released, some pressure is trapped anywhere in the normal or alternate systems. On ground, when the pressure of at least one wheel is above 15 bar with the pedals released, there is a «Master Caution» with audible sound and visual indications in the page WHEEL of the ECAM. This caution is inhibited in the ground when the speed is higher than 80 kt and during takeoff, climb, cruise, descent and landing until the speed is below 80 kt.

The page WHEEL is automatically shown in the ECAM every time «landing gear down» is selected, even when there is no caution or warning in the system.

1.6.2.5. Schematics of the alternate brake system

A brief and schematic description of the physical layout of the brake system of the A-340 is presented here below, together with its situation when the alternate system is working. For that purpose, the attached Figure 3, copied from a familiarization training course of the manufacturer.

As it can be seen in the figure, the automatic selector allows the pressure of the alternate or «blue» system is feeding the brake circuit. The brake distribution dual valve (BDDV) or «dual valve» is a very important component of the system, and each of its sides is activated by an auxiliary low pressure circuit that comes from the pedal of that side. When the pedal is pressed, that low pressure activates the corresponding side of the BDDV (as represented in the figure), in such a way that the blue pressure reaches the «alternate servo valve». This servo valve opens or closes as controlled by the BSCU that in turn receives information from the antiskid when it is active, as it happens in the condition represented in the figure. In such a case, the pressure is regulated to keep an optimum rate of braking with a certain amount of slip of the wheels determined by the design of the system and the wheel do not lock even when the pedals are fully pressed.

However, if the switch A/SKID & N/W STRG that can be seen in the figure is moved to the OFF position, the BSCU is disconnected and the servo valve is fully open, and therefore any hydraulic pressure of the blue system called upon by the BDDV is transmitted all along to the brakes. Under those conditions, the pilot must carefully watch the triple indicator (also represented in the figure) to keep the pressure on each side or leg of the MLG at 1000 psi as a maximum, because otherwise there is a risk to lock the wheels and almost certainly burst them.

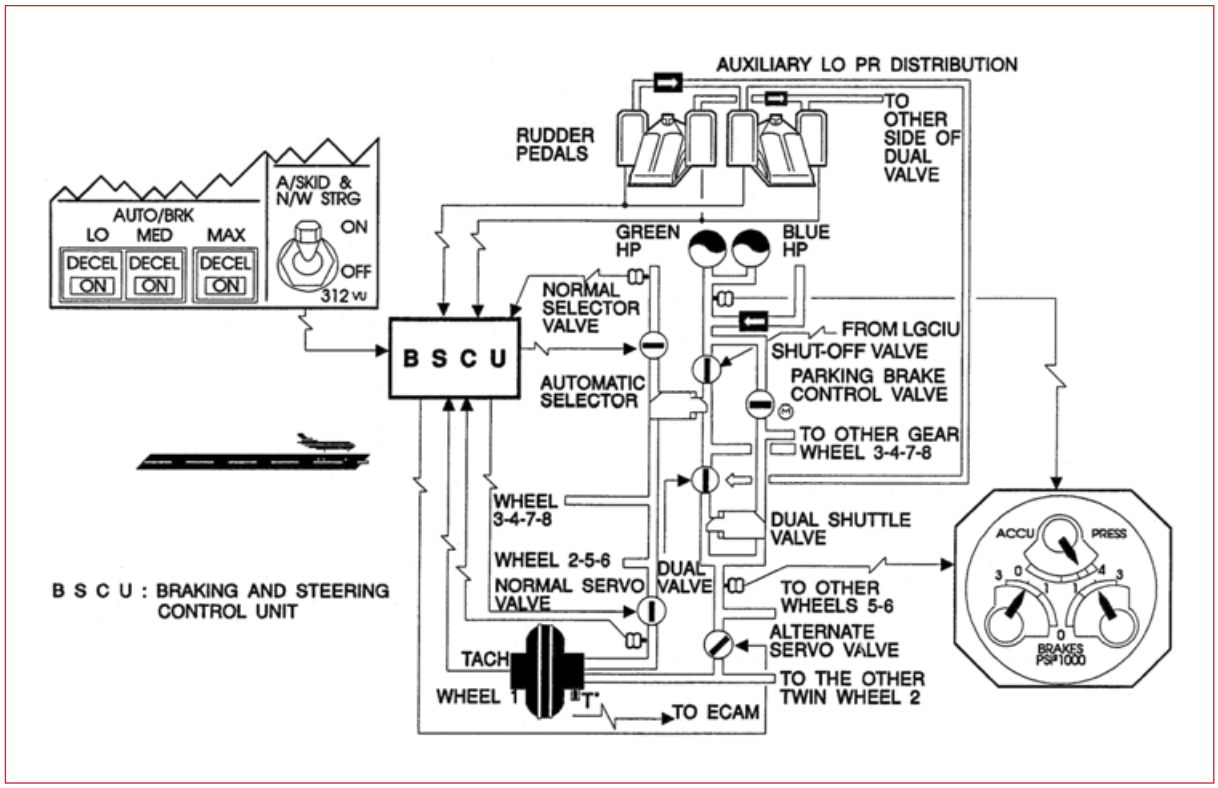


Figure 3. Schematics of the brake system. The alternate system is operating with the antiskid system ON in the represented condition

When the alternate brake system is active, each pedal applies pressure to the auxiliary low pressure system through a master cylinder that can be seen in figures 1.6.2.5.2 and, in greater detail, 1.6.2.5.3. When there is no force F applied, the chambers C1 and C2 are communicated and full of hydraulic fluid because the valve is kept outside its seating by the spring R2. When the pedal is pressed (force F) the sliding assembly is compressed downwards against spring R2 and there is initially a dead travel. The hydraulic fluid goes from chamber C1 to chamber C2 and comes out through port B. If the pedal deflexion continues, when the dead travel ends, and the preformed packing moves with the sliding assembly up to it is pressed against the valve, in such a way that the flow between chambers C1 and C2 is cut, and pressure in chamber C1 starts raising. The sliding assembly moves the valve and presses springs R1 y R2 and produces the reduction of the volume of chamber C1 and the fluid flows out through port A towards the dual valve (BDDV). The pressure in chamber C1 is proportional to the resistance opposed by the hydraulic fluid in the external system connected to port A.

If the brake system is in normal mode (with green hydraulic pressure), the movement of the pedals is electronically sent to the BSCU that processes the intention of the pilot and the information of the antiskid system to command directly the normal servo valve and to apply the corresponding pressure to the wheels. The dual valve does not work in that condition.

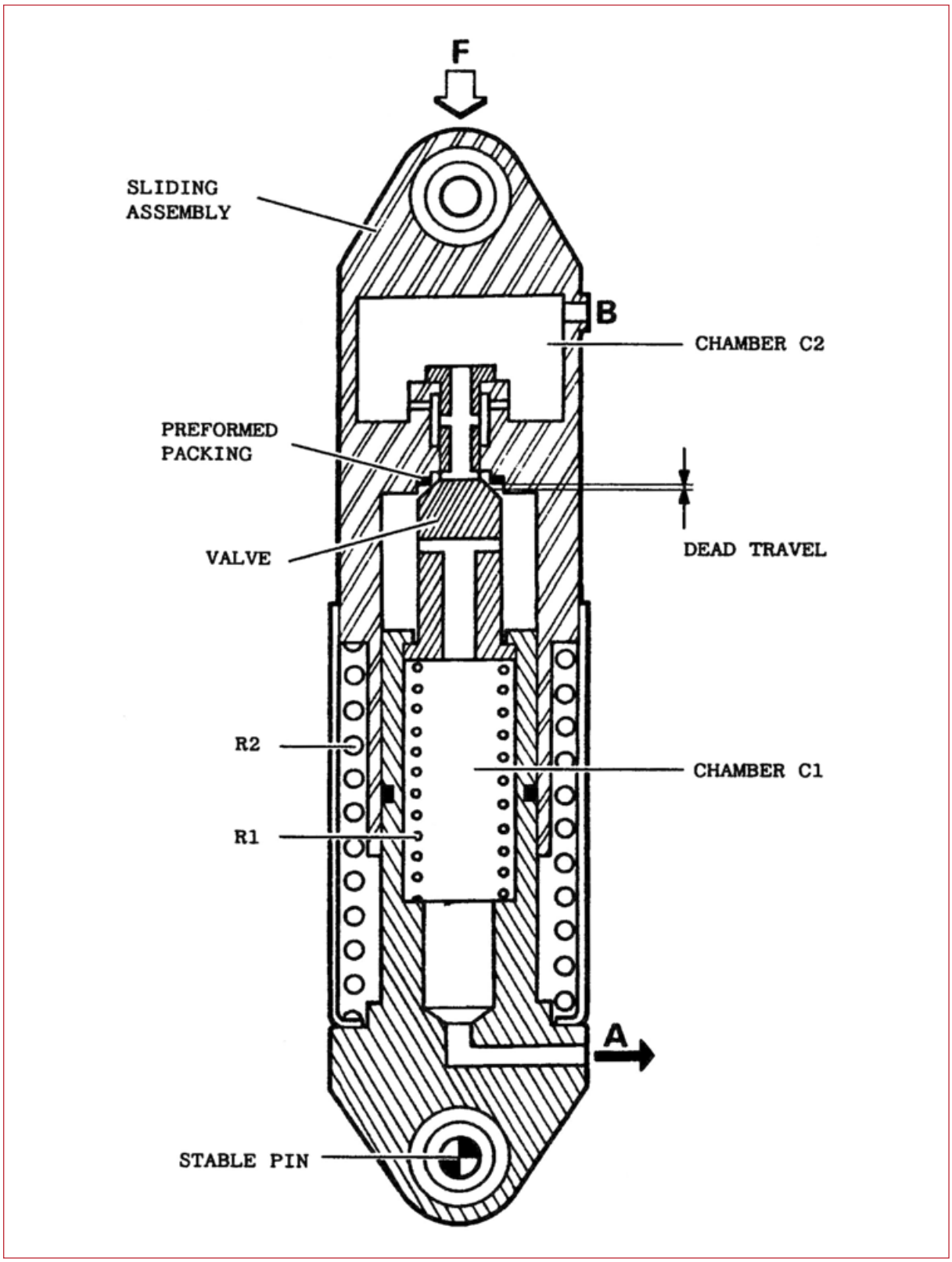


Figure 4. Drawing of the master cylinder. When the pedal is pressed, a force F is applied in the upper part of the cylinder

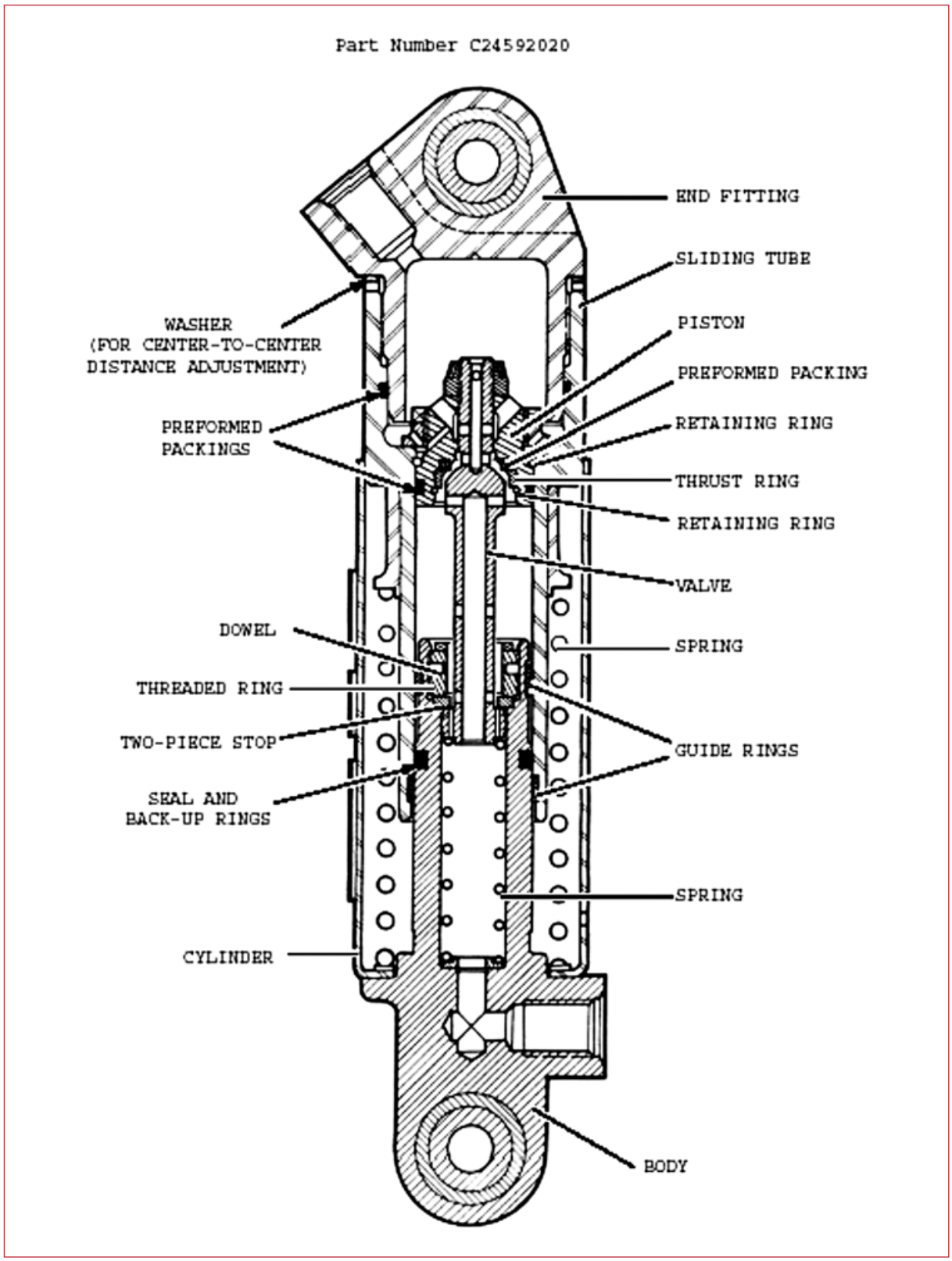


Figure 5. Detailed cutaway of the master cylinder

According to the Component Maintenance Manual (CMM) «Master Cylinder C24592020», dated 31 July 1992, the total length of the cylinder must be between 170.050 mm and 170.100 mm, and the dead band must be between 0.4 mm and 0.5 mm (there was a typo in the CMM, page 703, in which it is mentioned «*dead travel 0,4 to 05*»).

1.6.3. *Abnormal and emergency procedures related to the brake system*

1.6.3.1. Abnormal procedures

The Operations Manual prepared by the operator in Spanish language, Paragraph 3-02.32, dated 20-3-2001, mentions two abnormal procedures related to the circumstances of the event:

«BRAKES A/SKID FAULT» AND «BRAKES A/SKID NWS OFF»: (English translation) The first warning appears in the event of antiskid failure and the second when the switch A/SKID & N/W STRG is in OFF. In both cases, the maximum brake pressure must be 1000 PSI, and the brake pressure must be watched in the triple indicator. The effect of brake application is much higher than in normal mode and therefore the pedals must be pressed smoothly without exceeding the mentioned pressure. The landing distance increases by 1.4.

«BRAKES RESIDUAL BRAKING» (dated 30-4-2002): (English translation) If the warning appears on ground, immediately after engine start or during taxi, make a reset of the BSCU selecting the switch A/SKID & N/W STRG to OFF. If the warning does not disappear a maintenance action is required. NOTE: to make the reset of the BSCU it is needed that the aircraft is still and the parking brake applied. The indication «ON BRAKE 1 (2, 3, 4, 5, 6, 7, 8») appears for the information of the crew when there is brakes residual pressure affecting one or two wheels.

In this latter case that brakes residual pressure appears in any of the wheels (amber bar on those wheels) there is no instructions about what the crew must do. There is no clear indication in the abnormal procedure whether the warning appears in flight, on ground or in both cases (see 1.6.4.4. above with the description of this indication copied from the Operations Manual, Chapter «Systems»).

For the understanding of the circumstances of the incident described in this report, it is very important to distinguish between the CAUTION of «brakes residual pressure» and the INDICATION of «residual pressure in wheel(s) number X, Y...».

— The caution consists of an audible gong, MASTER CAUTION light, and the text «RESIDUAL BRAKING», and may only appear on ground. In flight the caution is inhibited, even though there is actual residual pressure. When it appears on ground, the Operations Manual of the operator requests that a reset of the BSCU be made and, if the caution continues, to call Maintenance.

— The INDICATION (vertical bars in amber colour in one or more wheels) may appear on ground or in flight when the page WHEEL of the ECAM is displayed, which always happens automatically when landing gear is selected down. When this indication appears, the Operations Manual does not provide any procedure to be followed.

The Flight Crew Operating Manual (FCOM) prepared by the manufacturer of the aircraft differs from that prepared by the operator about the actions to be taken in the event a «RESIDUAL BRAKING» caution is displayed (always on the ground), because there is no mention to make a reset of the BSCU, but simply to call Maintenance.

However, the SOP of Airbus does require making a reset of the BSCU in Chapter «Supplementary Techniques» (3.04.32 P1) where they say: «In case of braking/steering difficulty, the crew may perform a BSCU reset to recover correct functioning of the system. In particular, this applies to the following ECAM Warnings: ... Brakes residual warning». Also the «Technical Follow-up» issued to cover the appearance of residual pressure in flight and the «Flight Operations Telex» on the same subject (see paragraph 1.6.3) mentioned the possibility of making a reset of the BSCU.

The SOP of the manufacturer do not allow making a reset of the BSCU in flight with the landing gear down.

The FCOM de Airbus did not provide, in the date of the incident, instructions about what to do if INDICATION (amber bars) of residual pressure was noticed in some wheel during flight.

1.6.3.2. Emergency procedures

The only emergency procedure related to the brake system included in the Operations Manual of the operator (3.01.32, 1-10-2000) is the following:

> *«PÉRDIDA DE FRENADA»: (English translation) if brakes are not available, maximum thrust reverse, release the brake pedals, disconnect the switch A/SKID & N/W STRG, carefully press the brake pedals, limit the brake pressure to 1000 PSI, check the BRAKES PRESS indicator, and maintain directional control with differential braking as the nose wheel steering is not available. If still brakes are not available, the parking brake must be used making short and continuous applications of the parking brake to stop the aircraft. At the beginning of each parking brake application some asymmetric braking could appear. When ever possible, the application of the parking brake must be delayed until the speed has decreased, to reduce the risk of tire burst and difficulties in directional control.*

1.6.3.3. Checklist in final

The Operations Manual prepared by the operator, Chapter 2.01.63, 15-10-2001, says that

«(English translation) The checklist of FINAL is read by the PNF, at request of the CM-1, and is answered by the CM-1 and the CM-2 as applicable. Its completion guarantees that the aircraft is safe for landing. The checklist of FINAL appears in the E/W D of the ECAM below 1500 ft with the landing gear extended.»

«A/THR CHECKED SPEED OR OFF
LDG SIGNS ON
LDG GEAR DN
FLAPS LDG
SPLRS ARMED
Checklist of FINAL completed.»

1.6.4. *Previous maintenance on the aircraft*

The aircraft suffered a bird impact in the nose area on 28-7-2002, when it was approximately at 7000 ft of altitude, and as a consequence repair maintenance was carried out in which a technical team of the manufacturer provided on site support, and during which the brake pedals were disassembled and then assembled again as a whole assembly, in other words, the subcomponents of the pedal assemblies were not dismounted. After the repair, the team of the manufacturer conducted a complete operational test of the alternate brake system, according to AMM Task 32-43-00-710-801. The results were OK.

At that time, a scheduled inspection A-2 was carried out when the aircraft had 957 h of flight.

The day of the incident the aircraft made its first flight after those maintenance tasks.

1.6.5. *Previous incidences in the brake system of aircraft EC-IDF*

The following abnormalities related to the event were reported in June 2002:

Date	Abnormality	Corrective action taken
07-06-02	When the LG is lowered residual pressure appears in left wheels 1, 2, 5 and 6 with subsequent heating.	Carried out System Test BSCU channels 1 and 2 Test OK. Carried out System Test BSCU «Norm BRK» in channels 1 and 2 Test OK.
08-06-02	In descent with clean configuration the brakes residual braking lights on brake 1, 2, 5 and 6, at parking 500 °C+ of temperature reached.	Test of BSCU channel 1 and 2 results correct.

Date	Abnormality	Corrective action taken
09-06-02	In the landing the message residual Braking appears in wheels of left leg (N° 1-2-5-6), it disappears after a reset in the parking.	The servovalve connectors are cleaned and the pressure transducer of wheels associated (9GG1, 10GG1, 11GG1, 12GG1 and 5-6-7-8GG1). It is inspected the status and condition of dual valve (5403GG), *Master Cylinder (5422GG)* and filter LP-B RSVR (5011JM2) and no abnormalities found. System Test and Normal BRK Test of both BSCU OK.
10-06-02	In approach residual pressure in left leg brakes. Solved after several resets of Nose Wheel Stering switch (there was indication of pressure in the brake indicator) and pressing the brakes at the same time. See previous reports.	Test of BSCU and reset of the brake system carried out, results OK.
11-06-02	At landing appears in the ECAM «Residual Brakes» in the left leg.	the residual pressures in left leg are checked, OK. It is verified the accumulators Sys Blue OK. Cleaned transmitters 3GK1 and 3GK2. Sys Test to BSCU from MCDU carried out. The message in ECAM disappears.

According to the information gathered, those abnormalities were not reported to the manufacturer. However, similar squawks were reported to Airbus in year 2001 due to the residual pressure that appeared in aircraft EC-GUP.

Late in the investigation process, the operator stated that AMM Task 32-43-00-710-801 «Operational test alternate brake system» was carried out on 11 June 2002 (the day of the last squawk). They said that, although the task was not specifically recorded on the logbook, the technician recorded other actions like checking the free rotation of the wheels that are a part of the task. This is the last action to be carried out after the application of TSM task 32-40-00-810-927 (see below). Regarding this task, they also stated that the «fault confirmation» (look at the triple indicator to see if there is pressure) was also carried out on 11 June 2002 (see table above).

The manufacturer was indeed aware of other indications of residual pressure, and they had issued the «Technical Follow-up» (TFU) 32.42.21.002 «Brakes residual braking ECAM warning» in September 2000 in which it was mentioned that the warning used to be due to a spurious indication, caused by the pressure transducers or by the monitoring of the BSCU, although it was also stated that the residual pressure could also be real. The TFU mentioned the possibility of resetting the BSCU using the switch of the antiskid. The TFU also called for two troubleshooting procedures, which would detect whether the pressure indication was real or spurious. Both tasks (32-40-00-810-839 and

885) started with a built-in test of the BSCU, which was the corrective action taken by the maintenance personnel in most of the reported cases, with results OK. According to the tasks, the BITE test would act as a confirmation of the real nature of the residual pressure.

This TFU was closed in August 2003, once the Service Bulletins A340-32-4187 and A-340-32-4193 were issued by Airbus to solve the problem of spurious indication.

The manufacturer also issued the FOT 999.0030/002 «BSCU Reset subsequent to a brakes residual braking» dated 19-04-2002 in which the spurious messages of residual pressure were described and the need to make a reset of the BSCU was mentioned.

The different documents issued by Airbus before the incident were due to a history of residual braking indications, that, as previously mentioned and among other aircraft, affected to A-340 EC-GUP also operated by IBERIA. Within 1-11-2001 and 23-11-2001 there were several reports on that aircraft involving residual pressure indications, both on ground and in flight. Those reports were reported to Airbus, which worked closely with Iberia to try to solve the issue. A lot of communications took place at and after those dates between Iberia and Airbus. Several troubleshooting procedures were proposed and several components were replaced on EC-GUP until the problem finally disappeared.

The manufacturer stated that Iberia had never formally informed them of the results of the recommended troubleshooting actions of EC-GUP.

Furthermore, the manufacturer added that TSM task 32-40-00-810-927, which is named «Brakes alternate system has residual pressure in the left MLG», should have been applied at since the beginning after the five reports in June 2002. They said that TSM task requests the replacement of the master cylinder if the fault cannot be reproduced on ground.

The entry points for this TSM task were analysed by the manufacturer after the incident and they provided evidence that several of the clues present during the squawks in June, like the «BRAKES RESIDUAL BRAKING» caution, the displayed amber bars, or the CMS fault message «MASTER CYL L(5422GG)/DUAL VALVE (5403GG)» would have led to the mentioned task 32-40-00-810-927.

This task consists of the following actions as applicable to the present incident:

« .../... (other text)

3. Fault confirmation.

A. Test.

(1) On the panel 117VU, put the parking brake to OFF.
(2) If the lower left indicator of the triple pressure indicator (2GK) shows a pressure, depressurize:

— The Blue Hydraulic system
— The reservoir of the Blue Hydraulic system
— The Park Brake accumulators

4. Fault isolation

A. Procedure

(1) If the lower left indicator of the triple pressure indicator (2GK) shows a pressure: replace the PRESS XDCR-BRAKE, BLUE L.../...(otro texto)

B. Procedure

(1) If the lower left indicator of the triple pressure indicator (2GK) does not show a pressure: replace the MASTER CYLINDER-ALTN BRK L, CKPT (5422GG)
(2) If the fault continues: replace the DUAL VALVE-ALTN BRK.../...(other text).
(3) If the fault continues: replace the FILTER-LP, B RSVR.../...(other text)

C. Test

(1) Do an operational test of the alternate brake system (Ref. AMM Task 32-43-00-710-801)»

The TSM introduction explained on pages 8 and 10 the meaning of «Fault confirmation» in case of «Permanent fault» and «Intermittent fault».

In the first case, the «fault is confirmed on ground by performing the test required in the fault confirmation paragraph. Consequently, the procedure must be applied to troubleshoot the aircraft».

In the case of an «intermittent fault», specific instructions are provided as follows:

«The fault is not confirmed on ground by performing the test required in the fault confirmation paragraph. Faults are sometimes generated by electrical transients or similar events without the aircraft system being faulty. If the confirmation test result is "TEST OK" or equivalent, no further action is required (unless specified in the fault isolation procedure). The aircraft may be dispatched. It is recalled that the TSM has

been designed to isolate/troubleshoot hard faults. However depending on the airlines organization, the following can be applied "to trap" intermittent faults:

— *if test OK (fault not confirmed) dispatch the aircraft, then perform a monitoring of the reported symptom on the following flights by checking:*

– *the previous leg reports*
– *the PFR/Previous PFRs (if available)*
– *the log book of the previous flights*

after 3 occurrences of the same phenomenon (even through the test still OK), the other steps of the TSM procedure shall be followed and the LRU involved be removed. (other text).

— *if test NOT OK (fault confirmed), apply the trouble shooting procedure.»*

The manufacturer was consulted regarding the practical way of carrying out the task -927 in this case, and they answered that, because of that «intermittent failure concept», the -927 procedure should have been applied completely, including the replacement of the master cylinder on the 9th of June 2002 (after the third squawk). The maintenance personnel of the operator had a different interpretation because they seemed not to be applying the intermittent failure part of the TSM, and they said that if there is no pressure in the triple indicator at the beginning, there is no «Fault confirmation» and therefore the task ends. They added, late in the investigation process (see above), that even though this fault confirmation failed because they checked the pressure in left leg on 11 June 2002, they still applied the operational test 32-43-00-710-801 to be sure that the system was OK.

1.7. Meteorological information

The METAR at Madrid-Barajas Airport on 7-9-2002 at 13:00 UTC was:

LEMD 071300Z 23011 KT 180V250 9999 FEW080 SCT150 27/07 Q1016 NOSIG

The information gathered shows that the temperature of the atmosphere in the province of Madrid at 13000 ft of altitude approximately matched that of the International Standard Atmosphere (ISA).

1.8. Aids to navigation

They do not affect the circumstances of this incident.

1.9. Communications

The communications worked normally all the time during the incident. The relevant communications of the conversations with the control towers of Tenerife Norte and Madrid-Barajas has been reproduced in other parts of this report.

1.10. Aerodrome information

1.10.1. *Airport of Tenerife Norte*

This airport has an asphalt runway, 12-30 of 3400 × 45 m. The runway stripe has 3520 × 300 m.

The aerodrome category for rescue and fire fighting is 8 (aircraft of less than 61 m of total length and 7 m of maximum fuselage width).

1.10.2. *Airport of Madrid-Barajas*

The airport has three asphalt runways: 33-15 (4100 × 60 m), 36R-18L (3700 × 45 m) and 36L-18R (4350 × 60 m). The runway stripe has a width of 300 m in all of them.

The aerodrome category for rescue and fire fighting is 9 (aircraft of less than 76 m of total length and 7 m of maximum fuselage width).

The day of the incident runway 33 was being used for landings and runway 36L for takeoffs. As a consequence of the incident, when runway 33 remained out of service, runway 36R was open for landings.

1.11. Flight recorders

1.11.1. *Cockpit voice recorder*

The aircraft had a solid state cockpit voice recorder (SSCVR) Honeywell P/N 980-6022-001; S/N 6393705700, that is able to record the latest 120 minutes of the voices and sounds in the cockpit in four channels. Channel 1 records the sound of the headphones and boom microphone in the pilot in command position; channel 2 records the sound of the headphones and boom microphone of the copilot position; channel 3 the sound of the headphones and boom microphone of the flight observer position; and channel 4 the cockpit environment sounds through the area microphone.

The recorder starts recording since the moment the first engine is started, and keeps continuously recording the sound of the four channels until five minutes after the last engine has been shut down. It can also operate in manual mode on ground.

The files corresponding to the 4 channels were downloaded and the sound could be reproduced with a good quality and made it possible to identify the text of almost all the conversations between the pilots and communications with the ATC.

Each channel had 2 h, 1 minute and 10 s of sound. Part of the flight from Tenerife Norte to Madrid had been recorded, exactly 1:21:29 (81 minutes and 29 seconds) elapsed before the aircraft stopped on runway 33 of Barajas, and then continued recording for 11 minutes and 54 seconds until the recording stopped because the engines were shut down. Then, a new recording period started with duration of 28 min and 5 s in which it could be heard the voices of maintenance personnel working inside the cockpit after the incident.

Therefore, the moments previous and later the incident itself were recorded and the pertinent information provided by the conversations and other sounds has been used in several parts of this report.

1.11.2. *Flight data recorder*

The aircraft was equipped by a digital flight data recorder (DFDR) able to record the latest 25 h of a total of 663 parameters of the aircraft. The reading of this DFDR was carried out without problems in a laboratory with capacity for it and the relevant information provided by the different parameters has been reproduced in several parts of this report.

The DFDR also showed the following actions of the flight crew:

— During the cruise flight to Madrid the pages of ECAM were not deployed to check the status of the different systems.
— The spoilers were not armed during the landing in Madrid.

1.12. Wreckage and impact information

The aircraft came to a stop besides the left side of runway 33, with its longitudinal axis rotated around 10° with respect to the runway axis and with all its wheels on the asphalt area.

The left MLG leg was beyond the runway edge lighting line, and remained approximately at 5 m from the runway shoulder end, that is, at 40 m from the axis of runway 33, that has 60 m of total width (distance between the white lines of runway edges), and at 146 m from the axis of the taxiway J-1. The nose landing gear also remained at approximately 5 m from the runway shoulder end and at approximately 120 m from the axis of taxiway J-1.

Therefore, that left MLG leg remained at 313 from the intersection of the axes of runways 33-15 and 36R-18L.

When the runway could be inspected, it was noticed that starting in the point the aircraft had stopped and coming back in the sense towards the threshold of runway 33 (i.e. going in the sense contrary to the movement of the aircraft during the landing roll), tracks of the wheels of the left and right MLG legs could be clearly noted. The tracks consisted of eight dark lines that corresponded to the sides of the tires showing that all the wheels had burst. At 60 m form the point where it was stopped, the track of the left leg crossed the runway edge lighting line (at 2 m from the next runway edge light), and 60 m backwards it crossed the white line of the runway side stripe. During the previous 60 m it could be seen that the wheel rims number 1 and 5 (both outboard wheels of the left leg) had dragged along the runway, although no appreciable grooves or other damage to the runway surface was noticed.

At 240 m from the point it finally stopped (i.e., at 73 m from the intersection of runway 36R), the tracks of the right MLG leg disappeared at a point located 8.2 m to the left of the runway axis.

The tracks of the left leg continued being visible going backwards, they crossed the intersection of runway 36R and started softening and blurring being confused with the tracks of other aircraft 630 m aft of the point where the aircraft stopped (i.e. at 900 m from the threshold of runway 33).

The damage to the aircraft consisted of the burst of the eight wheels of the left and right legs and damage to the brake assemblies number 1, 5 and 6 with the following description:

Wheels 1, 2, 5 and 6 showed heavy rubbing with loss of material of the rim and tire burst, due to friction with the runway.

Wheel 3 had friction in the rim and tire burst due to contact with the runway.

Wheel 4 had friction in the rim with loss of material and tire burst due to friction with the runway.

Wheels 7 and 8 showed tire burst due to friction with the runway but the rims did not have noticeable damage.

Figure 6. Wheels 3, 4, 7 y 8 (right leg; seen from the rear right angle) after the aircraft stopped on the runway. The white line is the runway side stripe marking of 33. Note the two narrow tracks of every wheel after they burst

The brake assemblies 1, 5 y 6 showed heavy rubbing with loss of material in the fitting and in the brake disks, due to friction with the runway.

When the aircraft was inspected in a hangar, there were no signs of fire having affected the landing gear. The lower part of the wing and the inboard flaps did not show any traces of smoke.

The maintenance personnel of the operator replaced the wheels of the aircraft on the runway and then the aircraft was towed to a hangar.

1.13. Medical and pathological information

There were no personal damages during the event.

1.14. Fire

At Tenerife Norte Airport there was no fire, although there was smoke coming out the wheels due to the high temperature reached by the brakes.

At Madrid-Barajas Airport, a lot of smoke was seen from the tower immediately after the incident. Another aircraft said on the radio that EC-IDF had fire on the wheels. The fire fighters were advised by the tower around 13:06 h, and at 13:09:45 h the crew confirmed to the tower that they were around the aircraft. At 13:09:55 h, the tower had already received confirmation from the fire fighting crew that the fire was extinguished.

According to their report, the fire fighters, which had been warned by the tower, reached the area of the incident and found all the wheels in fire, and they positioned around the aircraft and quickly extinguished the fire and then continued cooling the gears. They used a total of 250 kg of chemical powder and 1750 l of foam, although this later figure was higher than the amount normally needed due to the malfunction of one of the extinguishing vehicles.

According to some information gathered later on, the flames were clearly visible from the area of the south tower of the airport. However, when the aircraft was inspected in a hangar, there were no rests of combustion in any part in the wheel area.

1.15. Survival

There were no accelerations of such a high magnitude as to produce impacts in the passenger cabin. An emergency evacuation was not commanded, and the passengers left the aircraft in a normal way using air stairs provided to the aircraft and were taken to the airport with shuttle coaches.

1.16. Tests and research

1.16.1. *Ground test to locate the problem*

After the incident, the specialists of the manufacturer proposed to carry out a functional check of the brake system of the aircraft following a test plan outlined in the «Technical Disposition» of Airbus Ref. TD/B/2002/0341 (Issue 2), that basically consisted of trying to reproduce the residual pressure in the alternate system through the use of the pedals and the parking brake. If the residual pressure was not reproduced, then the flow rate during the bleeding of the left and right low pressure lines (between the BDDV and the master cylinders) should be measured to look for restriction points in the circuit. The details of the contents of the Technical Disposition are included in Appendix B. This pro-

cedure was not a part of the previous maintenance documentation of the aircraft. It was specifically prepared for the occasion after several weeks of work of the specialists of the manufacturer.

The test was carried out and it was found that the failure produced during the incident could not be reproduced, but the flow rate measurement showed that there was no flow in the left low pressure circuit while the flow in the right circuit was 50 cl in 20 s.

This meant that there was no way for the return flow from chamber C1 to chamber C2 through the left master cylinder (see Figure 4), that is, that there was no "dead band" and the pressure was trapped inside chamber C1 even when the pedal was not pressed at all.

This could be due to one of the two following factors:

a) The master cylinder was defective, with a length longer than the 170 mm specified, in such a way that is should be compressed when assembled in the aircraft, producing the closure of the valve.

b) The rigging of the left pedal was defective, in such a way that the cylinder, even having the correct length, had still to be compressed during assembly, again producing the already mentioned closure of the valve.

The master cylinder P/N C 24592020 (Functional Item Number 5422GG), S/N H2121 was replaced by other master cylinder off the shelf and the flow rate test was done again, and this time a flow of 50 cl in 25 s was obtained. With this result, the specialists of the manufacturer confirmed that the master cylinder was defective and was the component producing the residual pressure. Pedal rigging pins were installed to confirm correct rigging of the pedals.

The master cylinder was sent to its vendor-manufacturer, Messier-Bugatti, for a detailed inspection and teardown.

1.16.2. *Release to service of the aircraft*

After the replacement of the master cylinder mentioned in the previous paragraph, the specialists of the aircraft manufacturer issued the Trouble Shooting Report N° 3048/SEE32/TSR/1002 that confirmed that «the original master cylinder was faulty and was the sole cause of the residual braking behaviour. Also, it is confirmed that the pedal rigging is satisfactory». Although not specifically required by the manufacturer specialists, the operator carried out a flight test and it was noticed that after some time most of the pressure of the alternate brake system was lost, while the normal system functioned correctly.

Then the BDDV P/N 5403GG S/N H2718 was replaced and the brake system carefully purged. A new flight test showed that both brake systems functioned correctly and the aircraft was returned to service.

The replaced dual valve was also sent to Messier-Bugatti for additional inspection.

1.16.3. *Inspection of the master cylinder S/N H2121*

The master cylinder disassembled from aircraft EC-IDF after the incident was subject to several tests at the facilities of its manufacturer in Molsheim (France). The cylinder had been sent in a sealed package and it was intended to retain as much hydraulic fluid inside as possible.

The tests carried out were the following:

— Dimensional measurement: The length was 170.31 mm (the nominal value is between 170.050 and 170.100 mm). The «dead travel» was 0.58 mm (the nominal value was between 0.4 y 0.5 mm). The total travel was 21.68 mm (the specified value is 20.5 to 22.3 mm).
— Hydraulic fluid: the master cylinder was empty. It was not possible to recover hydraulic fluid for its analysis.
— Operational test: The graph load vs. travel was prepared according to the Component Maintenance Manual (CMM). It was observed that the results were outside tolerances in a series of points both in load (compression) and extension of the cylinder. For instance: with 10 mm of travel in load the force should be between 139 Nw and 153 Nw; the measured value was 162 Nw (7% above the specified limit).
— It was made a flow rate test under pressure. For that purpose, with the port B open, a pressure of 2.4 bar was applied to port A and the flow vs. travel of the cylinder was measured. In compression there was a flow of 2.17 l/min when there was no travel and the value of the flow was being lower. With 0.33 mm the flow was 0.01 l/min and with 0.34 mm there was no flow anymore. In unload of the cylinder there was no flow with 2 mm of travel, and the travel was reduced up to the moment that with 0.36 mm the flow started being 0.01 l/min.
— The cylinder was disassembled and no noticeable defects were found. The different subcomponents were dimensionally checked and all of them were found inside tolerances except the «small» spring or spring valve (spring R1) that reached the nominal length with a load of 4 Nw instead of the 5 Nw of the specification. The specialists in the system considered this difference was not significant. The preformed packing of the valve was deformed because of the contact with the valve, and had no longer the squared section with which it was manufactured.

The cylinder was assembled again and it was adjusted in such a way that the length and the dead travel were the same as previously, and the operational and flow rate tests

were carried out again. The master cylinder was now inside specified limits during compression, but it was still slightly outside tolerances during the extension. A possible explanation for this behaviour was that some minute particles that were producing a lot of friction inside the cylinder could have been eliminated during the disassembly and reassembly. After this test the length was measured again and it had increased up to 170.35 mm. The dead travel had decreased from the previous 0.58 mm to 0.48 mm, and no clear explanation was obtained for this fact. The flow rate test provided the same results as previously.

Messier-Bugatti informed that those cylinders are manufactured by a subcontractor. The S/N H2121 passed its quality control after manufacture on 13-6-2000, and it was then recorded a dead travel of 0.44 mm (inside limits) and a total travel of 21.90 mm (inside limits), with the diagram load-travel inside tolerances. However, the length of the cylinder was not recorded during quality control acceptance tests at that time. Messier-Bugatti informed that «The unit is adjusted during assembly».

The acceptance test did not include a flow rate test under pressure.

Information gathered from technicians of the manufacturer indicated that they had never seen a cylinder with a length above specifications.

The master cylinder was reserved for further investigation at the facilities of Airbus in Filton (United Kingdom). See paragraph 1.16.5.

It was requested to Messier-Bugatti to provide an analysis of all the information retrieved during the tests in order to establish a hypothesis of the circumstances or the subcomponent of the master cylinder that made its length to be outside tolerances and that ultimately produced residual pressure in the alternate system of the A-340 EC-IDF.

Messier-Bugatti never provided a detailed analysis, but answered through an E-mail on 12-9-2003 that no subcomponent of the cylinder had been identified as defective, and that in December 2002 they had modified their procedures to include a systematic measurement of the length of every cylinder after manufacture. They also added that «remains a doubt as to the possible implication of other parts such as brake pedal assembly».

1.16.4. *Inspection of the dual valve (BDDV) S/N H2718*

The dual valve was disassembled from EC-IDF following a flight test carried out after the incident. It was subject to several tests at the facilities of its manufacturer Messier-Bugatti in Molsheim (France). The valve had been sent in a sealed package and it was

intended to keep inside as much hydraulic fluid as possible. However, the package was opened at Messier-Bugatti and only 1 ml of liquid could be collected.

The recovered fluid was observed in the microscope by specialists of the manufacturer of the component, who indicated that it contained some metal particles between 15 and 80 microns. There was not enough liquid to carry out a more complete analysis.

A functional test was performed in accordance with CMM 32-43-16, which includes a «Proces Velbal d'Essai» (test plan). All the results of this analysis were found inside tolerances. Messier-Bugatti stated that the valve was in normal operating conditions and was released as far as the investigation was concerned.

1.16.5. *Additional testing of the master cylinder S/N H2121*

The cylinder was sent to the facilities of Airbus in Filton (United Kingdom) to be put into a test bed to simulate the actual conditions of a flight of aircraft EC-IDF. The temperature changes that appear in climb, cruise and descent were considered as a main factor leading to the build-up of residual pressure in the alternate brake system.

Airbus carried out additional testing, but, even though the test conditions were more stringent, it was no longer possible to reproduce the residual pressure. However, because the cylinder had already been disassembled (see 1.16.3), the feasibility of those results was doubtful and had anyway to be analysed. It was concluded that, after disassembly, the master cylinder was no longer «the same» as during the incident. Therefore, no conclusion could be drawn from the additional testing.

1.16.6. *Inspection of the pedal cover*

Time after the investigations on the master cylinder took place, the pedal cover that was installed on EC-IDF upon delivery was pointed out as a possible cause of residual pressure. Therefore, an inspection for scratches and marks was carried out on that cover several months after the incident. The main function of that cover was to avoid that some foreign objects as pocked calculators or pens could fall to the brake assemblies.

The results of the inspection were:

1. There was no chaffing or scratching present on the MSN474 pedal assemblies covers.

2. All clearances between the pedal assemblies and their covers were sufficient to allow normal operation.

3. The operation of the pedal assemblies during braking inputs was normal.

4. The marks seen on the master cylinders of EC-IDF did not indicate any abnormality.

1.17. Organizational and management information

1.17.1. *Technical flight records of the aircraft*

On board the aircraft there should always be a block of forms of the aircraft flight logbook. Each form triplicates in 3 pages, from which the last (page 3/3, yellow colour) must always remain attached to the block. In the right upper area of the form there is a square titled «Capt. Acceptance» with a space for the signature of the pilot in command of the aircraft. There is a column called «Complaints» («Anormalidades») to be filled up by the crew, other called «Maintenance Actions» («Correcciones») to be filled by the maintenance personnel and other column of signatures of the maintenance personnel that have handled the complaints reported by the crew. The result of that handling may be «Fixed», «Under observation» or «Deferred».

The Basic Operations Manual prepared by the operator (revised on 26-5-2002), in paragraph 8.1.11, gives instructions to the flight crews to fill in the flight logbook forms, that basically are «All the required data in the form must be carefully completed». It is also stated that: «In the spaces reserved for the signature it is necessary no only sign, but to provide the identification number. The captain will sign the square of aircraft acceptance of the form corresponding to the flight that is going to be carried out. In this way, he will record the acknowledgment of the corresponding inspections, as reflected on page 3/3 of the previous flight logbook, and of the abnormalities and maintenance actions that are also written in this page 3/3 of the previous flight. This signature of the captain will also serve as confirmation of the complaints and data recorded during his flight. In the event there are no complaints, the word "NIL" will be written».

The «Manual de Procedimientos de Mantenimiento en red» («Maintenance Procedures Manual») of the operator (Section 2, Revision 7 of 18-6-02) also provides guidance for the handling and completion of the flight logbook pages. It is mentioned that the maintenance action after the reported complaints must always be done in accordance with the established documentation and, in the event that maintenance action or repair is not included in the documentation, the corresponding instructions will be consulted to the corresponding Engineering Support Department, and this circumstance will be reported in the flight logbook.

The MOE-145 («Maintenance Organization Exposition») and the "Manual de Procedimientos de Mantenimiento en red" (Section 2, Revision 7) contain instructions for the treatment of the flight logbooks by the line maintenance personnel and the transit inspections of the aircraft. It is stated that in the event the ground personnel find an

abnormality during their line inspection, even though it was not reported by the crew, they must record it in the column of «Maintenance Actions» of the logbook. In the description of the maintenance action reference to the corresponding part of the Maintenance Manual must be done.

In summary, the crew must review the logbook of the previous flight and the captain must sing the aircraft's acceptance in the logbook page of the actual flight been prepared, and this will show that he is aware of the disposition of the previous complaints. The signature will also validate the new complaints noted during his flight, whose maintenance actions will be accepted by the captain of the next flight, and so on.

1.18. Additional information

1.18.1. *Telex to the operators issued by Airbus Industrie*

On 31-10-2002 Airbus issued an «Operators Information Telex» in which the operators were informed of aircraft A319, A320, A321, A300, A300-600, A310, A330 and A340 of the circumstances of the event happened on 7-9-2002, and of the actions to be carried out by the crews in the event they noticed residual pressure in flight. The Telex said that in this case:

> «AS USUAL, THE NORMAL BRAKING AND ANTISKID SYSTEMS HAVE TO BE USED, AND THIS EXPLAINS WHY THERE IS NO ECAM/FCOM PROCEDURE EXCEPT [for A300-600 and A-310]. IN ADDITION, USING THE AUTOBRAKE (AS RECOMMENDED IN THE SOP) PREVENTS ASYMMETRICAL BRAKING DUE TO RESIDUAL BRAKING PRESSURE IN THE ALTERNATE BRAKING SYSTEM, SINCE ALTERNATE PRESSURE IS NOT SUPPLIED TO THE BRAKES WHEN NORMAL BRAKING IS ACTIVE.
>
> HOWEVER, IN THE LIGHT OF THE REPORTED EVENT, AIRBUS WILL PUBLISH SOME RECOMMENDATIONS FOR ALL AIRCRAFT, IN THE FCOM STANDARD OPERATING PROCEDURES' "APPROACH PHASE", TO AVOID SWITCHING OFF THE ANTISKID AND NOSEWHEEL STEERING FUNCTION, AND POSSIBLY TO ELIMINATE ALTERNATE RESIDUAL BRAKING PRESSURE.
>
> A330/A340 RECOMMENDATIONS DIFFER SLIGHTLY FROM THOSE OF THE OTHER AIRCRAFT TYPES, SINCE RESIDUAL BRAKING (FROM THE NORMAL OR ALTERNATE BRAKING SYSTEM) IS DISPLAYED ON THEIR ECAM WHEEL PAGE. ON OTHER AIRCRAFT TYPES, ONLY RESIDUAL BRAKING ON THE ALTERNATE SYSTEM IS VISIBLE, AND IS DISPLAYED ON THE TRIPLE INDICATOR.
>
> FOR A330/A340 AIRCRAFT (NOT APPLICABLE TO A340-500/600):

WHEN THE LANDING GEAR IS DOWN:

– ECAM WHEEL PAGE CHECK

– THE ECAM WHEEL PAGE APPEARS BELOW 800 FEET, OR AT LANDING GEAR EXTENSION.

– CHECK FOR THREE (A330), OR FOUR (A340) LANDING GEAR GREEN INDICATIONS.

– IF RESIDUAL PRESSURE IS INDICATED, PRESS THE BRAKE PEDALS SEVERAL TIMES. SELECT "AUTO BRK MED". IF RESIDUAL PRESSURE REMAINS:

  – BEWARE OF POSSIBLE BRAKING ASYMMETRY AFTER TOUCHDOWN, WHICH CAN BE CONTROLLED USING PEDALS.

  – DO NOT SWITCH OFF THE A/SKID & NWS: THE ANTISKID FUNCTION LIMITS THE EFFECT OF RESIDUAL BRAKING, AND PREVENTS TIREBURST.»

Additionally, Airbus modified the «Standard Operating Procedures», paragraph 3.03.19 of the «Flight Crew Operating Manual» (FCOM) to include the relevant information of the telex.

Before the incident, those recommendations were not included in any Airbus document.

1.18.2. *History of similar cases*

The manufacturer of the aircraft informed that they were aware of several cases of brake residual pressure in flight, and that it was known that most of those indications were spurious (see paragraph 1.6.3 with mention to the TFU issued to cover the matter). No failure of the brake system detected in flight had produced an incident that ended in tire burst during landing.

The operator informed (see 1.6.3) that in year 2001 there was a long period during which aircraft EC-GUP was affected by residual pressure, and they worked with Airbus to solve the problem.

1.18.3. *Other safety actions carried out by the manufacture of the aircraft*

In addition to the telex mentioned in 1.18.1, the manufacturer started a revision of their procedures of testing the brake system at the end of the assembly line and modified parts of the maintenance manual associated to the master cylinder.

They also started the study of a modification to the design of the master cylinder to avoid that environmental factors could produce the appearance of residual pressure in the brake system.

1.19. Useful or effective investigation techniques

None.

2. ANALYSIS

2.1. Operation during the Madrid-Tenerife flight

When the landing gear was lowered during the descent to Tenerife the crew observed in the WHEEL page of the ECAM that the 24 bars that represent the brakes of the wheels of the left MLG were lit in amber colour, indicating that there was pressure trapped.

Under those conditions, they did not check the triple indicator located in the central panel of the cockpit, which would have allow them to note that the pressure was in the left alternate system, not in the normal system.

Anyway, although the information recovered suggest that the crew did not recognize the origin and possible effects of the problem and they thought there was a «spurious indication», they made the right decision of landing with the antiskid connected, which was correct, and without autobrake, as they were used to do in occasions at the discretion of the captain.

However, they decided to retard the application of brakes to prevent possible braking problems in the event there really was a malfunction of the systems, instead of an indication failure as they suspected. The result of this decision was that during the time the brake pedals were not pressed, the alternate system was still active and, therefore, the 900 PSI of residual pressure that were present were transmitted to the left wheels, and the aircraft started deviating towards that side. At the moment of touchdown there were several pressure releases in the left brakes commanded by the antiskid system intermittently, and the wheels did not burst.

The copilot, that was the PF during the landing, applied right rudder as coherent with his intention to delay the brake application, until the deviation was very important, and the aircraft approached up to 8 m to the left edge of runway 12 and a decrease in the effectiveness of the rudder was noted as the speed was reducing. At those moments, he applied heavily right brake and also left pedal, until the aircraft deviated to the right of the runway axis and came to a stop. The right pedal application started when the aircraft had between 60 kt and 70 kt of ground speed, and reached its maximum value when the speed was 50 kt.

At the moment of pedal application, the green or normal system was activated and the residual pressure of the alternate system fell to 0 psi. However, when the speed was below 80 kt the pedals had not yet been pressed and there was still a pressure of 900 psi and, when the inhibition of the caution of «brakes residual braking» ended, this caution was displayed in the ECAM (see paragraph 1.6.4.4).

The result of those circumstances was that the crew was surprised by the behaviour of the aircraft, and they thought there had been a malfunction in the brake system that

remained during the landing roll, and that the brakes heated until the corresponding ECAM warning was displayed. However, the presence of the antiskid allowed an effective braking action and avoided the burst of the tires.

Once they had vacated the runway, the crew reset the BSCU. If at those moments they had checked the triple indicator or the ECAM wheel page, they would have noted that the residual pressure had disappeared, and therefore that action, required by the Operations Manual of the operator if the caution appears on ground, was not needed. The procedures of the manufacturer indicate in one chapter that maintenance action is required if the caution is noticed at engine start or during taxi, and in other chapter («Supplementary techniques» 3.04.32 P1) that the crew may reset the BSCU. That applies when the aircraft is on ground.

2.2. Maintenance actions in Tenerife Norte

When the aircraft was parked in the apron, the crew commented with the maintenance personnel the circumstances they had faced during the landing. At those moments, the immediate problem they had was a high brake temperature, which was cooled with fans.

From the information gathered it could be concluded that the ground maintenance personnel was fully aware of the problem of residual pressure that had to be handled during the previous descent and landing. They actually saw the «Post-Flight Report» provided by the aircraft that had recorded that the caution «Brakes Residual Braking» had appeared at 9:12 h in the phase «Cruise 06». This caution was not displayed to the crew at those moments, because it is inhibited. During the landing roll, below 80 kt, the warning was displayed at around 9:22 h when the inhibition ended.

However, the flight crew had not recorded any complaint or squawk in the flight logbook, neither the residual pressure appearance, nor the deviation during the landing roll, nor the high brake temperature.

The ground personnel took action to determine the origin of residual pressure, but did not write anything in the logbook. The maintenance procedures indicate that if the ground personnel detect any malfunction, they must write it down even when not previously reported by the flight crew.

Afterwards, the data gathered suggest that while the line maintenance personnel was trying to contact another department of the operator to seek support information to treat the problem of residual pressure, the boarding of the passengers started for the flight back to Madrid. This fact probably produced additional stress regarding the need to dispatch the aircraft as soon as possible. Anyway, given the facts that the residual pressure had disappeared and that the support personnel in Barajas could not

be contacted, the «transit check performed» box of the logbook was completed and, since there was not any complaint recorded in the logbook, theoretically there was also nothing to correct, and the doors were closed and the pilot in command decided to initiate the flight, with the understanding, according to his statement, that the aircraft was released to service. After the boarding, contact with maintenance people in Madrid was finally achieved, and the situation was commented but no further maintenance action was carried out. The maintenance personnel gave additional instructions to the crew, which in turn had decided that if during taxi any malfunction of the brake systems was noted, they would return to the parking area for additional maintenance action.

The captain did not complete the box «Captain Acceptance» («aircraft acceptance by the captain») of the next page of the logbook that pertained to the flight of the incident.

It is considered that it is possible that some doubts or misunderstandings existed regarding who had ultimate responsibility over the aircraft at every moment, but it would have been necessary to make additional efforts to understand with detail the causes and possible effects of the residual pressure in the brake system. The BSCU test was initiated but not completed. Therefore, the intended maintenance actions were not finished. In this case, the facts that the aircraft veered to the left and very high temperatures were achieved, including smoke coming out from the wheels, should have been sufficient to remove any doubt about the spurious nature of the fault. It should have been clear that the residual pressure had been real during the landing and therefore more troubleshooting was needed.

When the aircraft started taxiing again, the «RESIDUAL BRAKING» caution had disappeared and the crew did not report problems with the controllability of the aircraft during the taxi towards the runway and takeoff.

2.3. Operation during the flight Tenerife Norte-Madrid-Barajas

After the doors were closed and the taxi started, the crew came to the conclusion that the brake system was functioning normally, and proceeded with the takeoff. The landing gear was left down for some time to cool the brakes that still had a slightly high temperature. During the return flight to Madrid, the crew had at least two hours to study the actions to be taken in the event the residual pressure reproduced during the descent.

The DFDR data show that the pages of the ECAM were not displayed to check the status of several systems, as required by the Operations Manual (2.01.52, 15-09-200, «Watch the evolution of the parameters of the engine and aircraft systems though the ECAM, regularly calling the different pages...»).

During the descent to Madrid, the residual pressure in the left side of the alternate system had started to increase progressively when the aircraft was at 13000 ft.

At 12:58:02 h, the page WHEEL of the ECAM was deployed and the crew detected that pressure, because they saw in amber colour the 24 bars representing the left brakes.

The reaction of the crew was to reset the BSCU, moving to OFF and then to ON the switch ANTI SKD & N/W STRG, but the amber bars did not disappear.

Faced with this situation, the crew expressed their concern, because the preceding landing in Tenerife, where the deviation had been considered to be caused by the malfunction of some component of the brake system during the landing roll.

The residual pressure continued increasing and 500 psi were reached at the moment in which the landing gear was lowered, at 12:58:38 h when the aircraft was approximately at 4000 ft. At that moment, the page WHEEL of the ECAM was automatically deployed and the aircraft carried out several auto checks of the hydraulic system, and the normal brake system was momentarily connected and the residual pressure of the left side released until the checks finished and returned to its previous value.

They carried out another reset «cycle» of the BSCU, for 24 s. This action, carried out once the landing gear was down, was contrary to the operational procedures of the aircraft, and was unable to make disappear the amber bars, although they probably disappeared momentarily while the BSCU switched off and then on.

Should the crew checked and interpreted correctly the triple indicator, they would have noticed that the residual pressure was in the alternate brake system, which is not controlled by the BSCU. This could have help conclude that the resets of the BSCU would not be effective in the build up of residual pressure.

Under those conditions, there was a conversation in the cockpit in which it was said that one possibility would be to disconnect the antiskid, with the intention, according to the later statements of the crew, of avoiding that electronic systems not controlled by the pilots applied or released braking pressure in the uncertain conditions in which the whole system seemed to be. Finally they disconnected again the switch A/SKID & N/W STRG that was maintained in that condition for the remainder of the approach and landing. Thus, the possibility of activating the normal brake system (that had no residual pressure and that would have been activated at the moment of pressing the brake pedals) was precluded.

The autobrake system was not armed, and anyway it would not have functioned because the antiskid was disconnected.

The aircraft continued its approach and the crew commented the possible behaviour of the system during the landing. The conversations indicated that there were certain

doubts about the functioning of the brakes in the status they were. The copilot read the corresponding part of the Operations Manual, reminding clearly that the pressure should be checked in the brake indicator and that it should not be above 1000 psi any time, because otherwise the wheels would burst.

Almost simultaneously to the moment the tower authorized the landing in runway 33, with wind 210° and 10 kt, the crew decided to land close to the threshold of the runway and use reverse without touching the brakes. At those moments, the «Glide slope» warning of the GPWS sounded, with the aircraft at 600 ft of radio-altitude. The PF said that this warning should be disregarded because, according to a later statement, he wanted to carry out a somewhat low approach to touchdown as soon as possible.

On the other hand, with the time employed in the revision of the brake system in the manuals and deciding what to do regarding the residual pressure, it is very probable that the checklist of final was not read and completed (paragraph 2.01.63 of the Operations Manual of the operator). One of the consequences of this fact was that the spoilers were not armed during landing.

There were no special instructions given to the passengers and the tower was not advised that some abnormality with the brake system could appear, to allow the fire fighters to take positions with time in advance. As it happened in Tenerife-Norte, at least a high brake temperature could be expected that even produced smoke at that airport.

Those facts must be regarded as being a part of a situation with high workload and some uncertainty inside the cockpit. The workload would have been produced by the mental evaluation of the different malfunction scenarios of the brakes and the corresponding corrective actions, and the use of the manual, which eventually absorbed most of the attention of the crew at those final moments of the approach. Even though there was available time during the cruise flight, the crew was exposed to face the problem, look up for information and make decisions in the moments previous to the landing, after having lowered the landing gear.

The aircraft floated for 3 s in the flare until the right and left MLG legs touched down about 240 m after the threshold of runway 33, at 13:03:27 h. Since the antiskid was inactive, there was no momentarily release of pressure as it happened during touchdown in Tenerife. Therefore, when they contacted the runway, the left wheels where locked and it is probable that they burst soon afterwards.

Approximately 7 s later, the copilot asked whether the aircraft had a tendency to deviate. The captain and PF answered: «For the moment no», and added two seconds later: «Yes, it deviates, yes» and then «It departs a little bit». Seven seconds later the captain told the copilot to apply pedal and then to brake with the right brake. The copilot answered he was already braking.

At 13:03:45 h the right pedal was fully pressed, making the pressure of the alternate system of that side to increase up to 2500 psi, and the pressure of the left side to decrease down to 600 psi from the initial 800 psi of trapped pressure built-up during the flight.

The left pedal was not pressed any time and the aircraft finally came to a stop with all the wheels burst.

According to some braking marks noted in runway 33 after the incident, the first point where tracks of the bust left wheels are clearly noticed is 630 m rearwards the point of final stop of the aircraft (i.e. approximately 900 m away from the threshold of runway 33). This would indicate that initially the aircraft touched down (at 240 m from the threshold) and the residual pressure of 800 psi that was amassed in flight started actuating in the left side. To avoid the deviation the PF applied more and more right rudder, in a scenario similar to that faced in Tenerife, although now the pressure was 800 psi instead of 900 psi in Tenerife. At a given moment, the left wheels burst because they had touched down already locked, and from that point in which the aircraft had approximately 100 kt of speed, the directional control was much lesser because of the combination of decrease of effectiveness of the rudder with the burst of the tires, that initially decreased the braking force on that side.

The aircraft deviated in that area to the right of the runway axis to move then clearly to the left starting approximately at 100 m before the intersection with runway 36R. This fact could be due to the continuous decrease of the effect of the rudder and the loss of part of the left tires and dragging of the rims and brakes assembly along the runway surface.

The PF decided to apply right brake and 40 m after crossing runway 36R the right pedal started to be pressed until it reached its stop when the aircraft was 73 m beyond the intersection of both runways. In this point, tracks of the right wheels were first noticed in the runway. These tracks showed a heavy braking action until the right tires burst because a high pressure up to 2500 psi was applied. That braking action in the right side prevented the nose of the aircraft moving further to the left of the runway axis and from that point on the aircraft had a straight trajectory towards the runway left edge.

The left wheels crossed the runway side stripe marking in a point located 120 m before the final position of the aircraft, while the right wheel came to a stop just above that marking (see the white line of Figure 6).

Finally, the braking action (although reduced because of the burst of all the wheels) and that of the thrust reverses that were deployed after touchdown, allowed the aircraft to be stopped inside the asphalted zone, although with the left wheels beyond the runway edge lighting line.

2.4. Actions after the aircraft came to a stop

The information gathered indicate that although the fire fighters were not previously warned, at 13:09:55 h, that is, after 3 min and 55 s the tower activated the alarm, they had extinguished the fire of the wheels and had the situation under control. It took some time to the flight crew to receive information from outside the cockpit regarding the status of the aircraft.

The aircraft stopped at 13:05 h and at 13:05:41 h another aircraft informed by radio that the wheels were on fire.

Initially, the flight crew were evaluating the need to shut down the engines, advise the cabin crew to be prepared or to order an evacuation. In the mean time, they called their company to request assistance. They were seeing fire fighters around the aircraft, but did not have clues of fire or smoke. At 13:08:24 h they addressed the passengers and the cabin crew members to advise them to remain seated without using the mobile telephones.

Therefore, there was a period of 3 min and 24 s since the aircraft was stopped until the passengers were addressed. During that period, the crew had some workload to communicate with the tower, to check the status of the systems of the aircraft, to evaluate the available information that was incomplete at the first moments, and to think of the options to be followed before informing the passengers.

The data retrieved in the investigation show that the air traffic control and airport services worked correctly in a coordinated manner all the time. The local air traffic controller (tower) that was controlling the traffic in runway 33 for landings kept the situation under control all the time. Runway 36R was immediately inspected and was open for traffic at 13:16 h (approximately 11 min after the aircraft came to a stop after the incident).

2.5. Origin of the residual pressure

The tests carried out on the aircraft and at the facilities of Messier-Bugatti led to the conclusion that the origin of the residual pressure in the left alternate brake system of the aircraft EC-IDF was the master cylinder P/N C24592020, S/N H2121 that, once disassembled from the aircraft, had a length of 170.31 mm (the nominal value was between 170.050 mm and 170.100 mm) and a dead travel of 0.58 mm (the nominal value was between 0.40 mm and 0.50 mm).

With those dimensions, the cylinder had to be compressed at the moment of assembly on the aircraft, in a way that made the dead travel to be 0.37 mm, which is 0.03 mm below the lowest tolerance of the specified value.

In those conditions, the alternate system could work in a normal way during a lot of flights or during a lot of phases of those flights, with the only difference that the aircraft would start braking with an angle of pedal deflexion slightly below the nominal value. However, due to the thermal expansion of the hydraulic fluid during the descent from cruise, under certain conditions, it is probable that the dead travel was plugged, thus preventing the return of hydraulic fluid from chamber C1 to chamber C2 of the cylinder, and eventually building up the residual pressure.

The master cylinder had passed its quality control after manufacture on 13-6-2000, and the dead travel was then measured to be 0.44 mm and the total travel 21.90 mm, with the load-travel diagram inside tolerances. The total length of the cylinder was not required to be recorded during the acceptance tests at that time. Therefore, it could not be documented whether the cylinder was already outside specifications after manufacture or whether the length of the part was unsettled later on, although it seems more probable the first possibility.

The defective internal subcomponent of the cylinder that was producing the difference in actual length with respect to the nominal length, or the part of the cylinder that was ultimately responsible for the build-up of residual pressure could not be determined. No detailed analysis of the behaviour of the component was received from Messier-Bugatti.

On the other hand, although Airbus carries out flight test after manufacture of their aircraft with duration of about three and a half hours, from which there are two hours at cruise altitude, and also the operator carries out acceptance flight tests, those flights did not detect any residual pressure. Since the flights did not include long periods of cruise at high altitude, it is probable that they did not produce thermal changes important enough during descent. However, the flight Tenerife-Madrid had a profile somewhat comparable to that of the flight tests (regarding time at cruise altitude) and there was indeed residual pressure.

2.6. Previous history of residual pressure

The aircraft was delivered by the manufacturer to the operator in May 2002. Until the date of the incident it had completed 131 flight cycles.

Since 7 to 11 of June 2002 there were five abnormalities reported regarding presence of residual pressure in flight in the wheels of the left leg. In the two first cases, there was an important increase of temperature of the brakes during the landing roll.

One of the squawks indicated «In descent with clean configuration the brakes residual braking lights on brake 1, 2, 5 and 6, at parking 500 °C + of temperature reached». Another report said: «In approach residual pressure in left leg brakes. Solved after seve-

ral resets of nose wheel steering switch (there was indication of pressure in the brake indicator) and pressing the brakes at the same time. See previous reports».

Additionally, in year 2001 there was a long history of residual pressure that affected A-340 EC-GUP of Iberia. The problem was reported to Airbus that worked with the operator to solve the problem. The TFU 32.42.21.002 stated that «Operator's reports have shown that the ´Brakes residual braking ECAM warnings are often spurious», although it was also mentioned that they could be real and troubleshooting was needed to confirm the fault. Airbus stated that they were never formally informed of the results of the recommended trouble shooting actions of EC-GUP.

Therefore, the maintenance personnel and several pilots of the operator were already familiar with the problem, and at least in one of the cases they had used several resets of the antiskid system to make disappear the pressure, although with the fundamental change of «pressing the (pedals) brakes at the same time». The deflexion of the pedal was recommended by Airbus after the incident as the way to release the residual pressure if noticed in flight (see paragraph 1.18.1). Previously, the manufacturer was not familiar with this problem, because, according to the information gathered, they had never received reports of actual residual pressure in flight from Iberia or from any other operator, and attributed any clue of pressure to spurious indications, and therefore recommended to reset the BSCU under some circumstances.

Those 5 reports of abnormalities could have contributed to prevent the incident on 7-9-02 if, from an operational point of view, the information on abnormalities had been provided to the crews of A-340, it is possible that the pilots of the flight of the incident would have been familiar with the situation and with the actions taken is similar cases.

Also, if from a maintenance point of view, they would have been more thoroughly investigated by the personnel of the operator, contacting with the manufacturer as needed, maybe the origin of the residual pressure would have been detected at that point. The manufacturer stated that high brake temperatures (that appeared in the first two squawks) were clear clues to indicate that the residual pressure was not spurious. Additionally, the analysis of the TSM carried out by the manufacturer showed that, with the available clues and indications, the task 32-40-00-810-927 should have been applied, at least after the third squawk according to the TSM introduction (see 1.6.5).

However, it remains doubtful that the application of this task in an isolated way by the personnel of the operator would have detected the faulty component and led to the replacement of the master cylinder. The task (see 1.6.5) requests a fault confirmation by means of setting the parking brake to OFF and then looking for pressure in the triple indicator. Since the residual pressure had an intermittent nature and was no longer present after the landings in June, maybe their interpretation would have been that this «fault confirmation» action had failed and therefore the rest of the TSM task would not

have been completed. Apparently they were not aware of the intermittent fault concept mentioned in the introduction of the TSM.

Since the TSM has been designed to isolate/troubleshoot hard faults, it is considered that the possibility of dispatching the aircraft until having 3 intermittent occurrences of the same phenomenon should be further analysed by the manufacturer, and some additional guidance should be provided in the TSM introduction. To avoid any confusion, it should be highlighted in pertinent parts of the TSM that all available clues must be carefully considered before dispatching again an aircraft after the first and second occurrences.

The operator also stated that they considered the instructions of the TFU should be applied in first place, and those instructions were not consistent with those contained in the Trouble Shooting Manual in this matter (i.e. the TFU did not refer to the proper TSM procedure). Therefore, they applied that TFU alone on the first two days of squawk.

On the third day (there was no high temperature reported that day) they also checked transducers, status and condition of dual valve, master cylinder, and filter, and they performed a system test and BSCU test. The transducer, dual valve, cylinder, and filter are mentioned in the task -927 (see 1.6.5), although no task was specifically recorded on the logbook and no component was replaced.

On the fourth day (with no high temperature reported) only the BSCU test and reset were carried out, which would correspond to the TFU instructions.

The fifth and last day (with no high temperature reported), it seems a mixture of tasks was performed, including checking of pressure in the left leg, cleaning of transmitters, test of BSCU, and checking of wheels free to rotate. Then the squawks ceased.

The operator stated, late in the investigation process, that an operational test of the brake system was carried out that day (11 June 2002), to be sure that the brake system was free of any trouble. That test is the last action of TSM task -927.

The manufacturer stated that the appropriate manual to be applied is the TSM, regardless of other ad-hoc maintenance information that may have been issued. The TFU was never re-issued to match the tasks of the TSM. This TFU was closed in August 2003, once the Service Bulletins A340-32-4187 and A-340-32-4193 were issued by Airbus to solve the problem of spurious indication. It is considered convenient to issue a safety recommendation regarding the need of consistency between the different maintenance documentation.

Additionally, it seemed that different interpretations existed of what to do after the «Fault confirmation» of the task 32-40-00-810-927, because the maintenance people

seemed to be unaware of the intermittent failure concept of the TSM, and therefore two safety recommendations on the matter are issued.

In summary, it seems that the intermittent nature of the residual pressure, together with differences of interpretation of the maintenance documentation or lack of knowledge regarding the meaning of «fault confirmation» for «hard faults» and «intermittent faults», masked the solution of the problem.

The operator also stated that they used to communicate with the manufacturer in many other instances of malfunctions reported by the flight crews.

The main factor that caused that the squawks in June 2002 were not communicated to Airbus was the awareness of the maintenance personnel, and even of most flight crews, of a long history of spurious cautions and indications associated to the BSCU, both in A-340 (including EC-GUP in year 2001) and in A-320, reflected in TFU and FOT of the manufacturer. Most of the corrections of the reported abnormalities included tests of the channels of the BSCU. In several instances, the correct result of those tests led to the conclusion that the caution or indication was due to a possible temporary malfunction of that component.

It seems clear that this factor influenced both the line maintenance actions in Tenerife and the decisions made by the flight crew. Additionally to the history of spurious indications, there was the fact that it was a new aircraft recently delivered, and their experience indicated that in the event of an unexplained indication, the probability of that indication being spurious was greater in that period.

In any case, apart from any previous history of spurious indications and from the interpretation of the available maintenance documentation, there were clues in some of the events (like high temperature after landing) to indicate that the pressure could have been real, although with an intermittent nature, and that more maintenance actions were needed.

Taking into account the maintenance carried out before the incident, it was considered necessary to issue two safety recommendations regarding enhanced analysis of reported intermittent malfunctions and enhanced training to the maintenance personnel focused to analysis of reported intermittent malfunctions.

After 11-6-2002, there were no further reports of residual pressure in flight until the aircraft had a bird impact on 28-7-2002 and was removed from service for repairs. Then, after the first flight since that repair, the incident happened on 7-9-2002.

In summary, since 21 May (start of operation of the aircraft) until 6 June there was no report of residual pressure. Since 7 to 11 of June there were 5 reports during 5 continuous flights, and then the pressure disappeared, or at least was no longer reported,

until it appeared again in the first two flights after the bird impact (Madrid-Tenerife and Tenerife-Madrid).

No evidence has been found to explain this behaviour. One hypothesis was that the maintenance tasks carried out during the fixing of the 5 complaints, together with the braking during those landings, eventually «corrected» in some way the behaviour of the left master cylinder. Then, in the repairs after the bird impact, the brake pedals were disassembled and re-assembled as a whole assembly to the fuselage, and no part or subcomponent of the assembly were removed in those operations. In paragraph 1.16 it is explained that the rigging of the pedals was considered correct in the tests carried out by Airbus after the incident.

In any case, it can be concluded that the tolerances and rigging of the master cylinder are so tight that, under certain conditions there may be susceptibility to environmental conditions simply by means of small deviations of those tolerances.

It seems clear that it would be positive that the design of the master cylinder was modified to make it more resistant to the influence of the mentioned factors. Airbus has already initiated this and other safety actions (see 1.18.3). It is considered convenient to issue a safety recommendation related to this fact.

2.7. Suitability of the operational procedures

The Operations Manual of the operator did not have any procedure to be applied in the event that residual pressure was detected in flight. Neither did have the Standard Operational Procedures (SOP) of the manufacturer.

When faced with this situation, a flight crew had the following options:

— To take no action, with the understanding that if the Operations Manual does not say anything, there is no need to do anything, and to land in a normal way, with antiskid connected and without delaying the application of brakes. If this had been the course of action taken in the landing in Barajas, the result would have been that at touch down (should the autobrake have been connected) or at application of left brake, the residual pressure would have been released and the braking action would have been normal.
— To seek technical support on the effects of the indication of residual pressure and the actions to be taken. This support could have been sought after landing in Tenerife but in flight, during the approach to Barajas and after having lowered the landing gear, it was much more complicated, because a go around would have been to be carried out to try then to communicate with the ground personnel of the operator.
— To make on board the decision to initiate some action to mitigate the possible effects of that indication based in previous experience. This was the option taken by

the crew in this case, using the negative experience they had in the landing in Tenerife in the same conditions of residual pressure, and therefore they decided to disconnect the antiskid and to delay the application of brakes as much as possible during the landing.

After the incident, the manufacturer issued a telex to the operators (see paragraph 1.18) and modified their SOP to clarify the actions to be taken by the crew under that situation. Among those actions is to leave the antiskid connected during the landing and to press the pedals in flight to release the residual pressure.

It is considered those actions are convenient to prevent similar events, because the previous SOP did not adequately cover that contingency, since an indication was described (amber bars in the page WHEEL of the ECAM) without clarifying whether it was displayed in flight, on ground or in both cases, and without providing instructions to be followed in that event.

In this case, a crew faced with that situation in flight, with no information on previous similar cases and without having seen it during training, as it was this case according to the information gathered, could be unsure whether the lack of procedure was due to an omission of the manual more than to the intend of the designers that no action was needed. A more comprehensive knowledge of the brake system would have helped the crew to make the right decision. Even though the reaction of other crews of the same operator that faced residual pressure indications in flight was not the same and those flights ended with no consequences, it is considered that a more detailed study of the brake system of the A-340 during training for initial type rating would be recommendable. The manufacturer stated that their recommended syllabus was enough for the crews to understand the brake system of the A-340. The operator devoted 6 h on the ground to study the electrical, hydraulic, landing gear and APU systems. Additionally, there was a four-hour session of flight simulator to cover ECAM and failures associated to electrical and hydraulic systems.

On the other hand, several discrepancies have been observed between the Operations Manual of the operator and the SOP of the manufacturer:

— The manufacturer specifically recommends using the autobrake except on very long runways where it is expected that braking will not be necessary, whereas the operator says that in a dry runway of normal length, normally the use of autobrake is not necessary.
— The operator requires to make a reset of the BSCU if the message «Brakes residual braking» appears on ground, while the manufacturer requires that Maintenance is advised in that case with no further action taken by the crew in the corresponding procedure of the SOP, although they allow the reset in the Chapter «Supplementary techniques». The text of the FOT of Airbus on the matter also mentions the possibility that the crew make a reset.

Information retrieved from several sources indicates that there was a culture among operators that the use of the autobrake appreciably increased the worn of the brakes and also the heating (sometimes with a negative influence in the dispatch of the aircraft). Therefore, in certain occasions it was intended to limit the use of this system by crews in runways with enough length.

After the incident, the operator required the use of autobrake in the procedure of the Operations Manual (2.01.63) in the event residual pressure was detected after lowering the landing gear.

Although there is no requirement for the Operations Manual of an operator is completely identical to the procedures recommended by the manufacturer, in this case, given the fact that both aspects could have influenced the outcome of the incident, it is recommended that the manufacturer clarifies whether or not a reset of the BSCU should be performed on ground when the caution is displayed. The operator should then adapt their Operations Manual to the conditions established by the manufacturer in this matter and also regarding the use of autobrake.

3. CONCLUSIONS

3.1. Findings

1. The pilots had valid licenses and were adequately qualified for the flight.

2. During the descent to Madrid-Barajas Airport the residual pressure of the left brakes alternate system started increasing when the aircraft was at approximately 13000 ft of altitude and it reached 800 psi when the aircraft was at approximately 500 ft of radio-altitude, at 13:02:45 h.

3. During the approach to Madrid-Barajas Airport, before lowering the landing gear, the crew observed in the corresponding page of the ECAM that there was residual pressure on the brakes of the left leg and, in absence of a procedure to be applied, switched off and then on the BSCU. Afterwards, they selected landing gear down and, with the gear down and locked, switched off the BSCU for 24 s and then switched it back on. They observed that there was still residual pressure on the brakes of the left leg, and disconnected again the BSCU moving the switch A/SKID & N/W STRG to the «OFF» position.

4. During the landing on runway 33 of Madrid-Barajas Airport the spoilers were not armed.

5. The aircraft touched down with the left and right legs of the MLG at approximately 240 m past the threshold of runway 33, at 13:03:27 h. After three seconds, thrust reversers were selected, they worked normally, and the spoilers started deploying.

6. The PF applied right rudder, without pressing the brake pedals, during the first 18 s of the landing roll.

7. Between 240 m and 900 m past the threshold of runway 33 the wheels of the left MLG burst because they were already locked when the aircraft touched down.

8. At 13:03:45 h, the right brake pedal was fully deflected (68°) and the pressure of the brakes alternate system increased up to 2500 psi, when the aircraft was approximately 70 m past the intersection of runway 33 with runway 36R.

9. At 73 m past that intersection there were track markings on the runway indicating that the wheels of the right leg bust in this area because they were blocked by the pressure of 2500 psi applied with the right pedal.

10. The eight wheels of the left and right legs of the MLG burst because of friction with the runway surface. The tire rims 1, 2, 4, 5, and 6 showed signs of rubbing

with loss of material by friction with the runway surface. The brake assemblies 1, 5 and 6 showed heavy rubbing with loss of material of the casing and the disks by friction with the runway surface.

11. There had been 5 complaints that referred to appearance of residual pressure in flight within 7-6-2002 and 11-6-2002 that were not notified to the manufacturer. There had also been several reports of residual pressure in other A-340 registered EC-GUP in November 2001, which had been notified to the manufacturer.

12. The aircraft made on 7 September 2002 its first flight since 28 July 2002, when it had suffered a bird impact and was subject to the corresponding repair.

13. The master cylinder, P/N C 24592020, S/N H2121, was the component that produced the residual pressure in flight. This cylinder had a length of 170.31 mm, which was 0.21 mm longer than specified. The dead travel of the cylinder (before being installed on the aircraft) was 0.08 mm longer than the value specified. The ultimate subcomponent inside the master cylinder that was causing the residual pressure could not be determined.

14. The Operations Manual of the operator, and the Standard Operational Procedures (SOP) of the manufacturer, did not contain procedures to be followed in the event residual pressure was observed in flight. Both manuals specified that if the antiskid system was inoperative, the braking is carried out with the alternate system, and the pressure applied to the brakes must not exceed 1000 psi.

3.2. Causes

It is considered that the cause of this incident was the fact that, as a consequence of the appearance of residual pressure in flight in the left brakes, due to the fact that the left master cylinder P/N C 24592020, S/N H2121 was defective, and due to the lack of a procedure to be applied in that case, the crew voluntarily disconnected the antiskid system when the residual pressure was still present, which produced the burst of the left tires at touchdown.

The following factors could have prevented the incident:

— The existence in the Operations Manual of instructions to be followed in the case of residual pressure being observed in flight.
— The knowledge by the affected flight crew of similar cases that had been reported as complaints during June 2002.
— A more comprehensive analysis of the previous squawks of residual pressure.
— A more detailed training on the brake system during the type rating courses.

4. SAFETY RECOMMENDATIONS

Airbus issued a telex to the operators in October 2002, and later on modified the FCOM to include instructions to the crew in the event of appearance of residual pressure in flight, and started a review of their procedures of checking the brake system in the assembly line of the aircraft. They also started the study of a possible modification of the design of the master cylinder to avoid the build-up of residual pressure in flight.

Messier-Bugatti modified in December 2002 their procedures of quality control after manufacture of master cylinders to include the checking and recording of the total length of every cylinder. However, it could not be determined which subcomponent of the cylinder, and the environmental conditions of operation, that ultimately produced the residual pressure in flight. Therefore, it is possible that such a pressure can appear again in aircraft A-340 equipped with this type of master cylinder, and it is considered necessary to issue a safety recommendation regarding this fact.

Iberia stated that they had established the «Centro de Control de Mantenimiento» (C.C.M.) with a view, among others, to improve the communication with remote maintenance units.

REC 09/04. It is recommended to the DGAC of France that, in collaboration with Airbus and Messier-Bugatti, conducts a deep evaluation of the characteristics of design, manufacture and maintenance of the master cylinders of the brake system of the A-340. This evaluation should have the goal of preventing that cylinders accepted by the different quality controls of the manufacturers at component manufacturer, final assembly, and flight testing, might produce residual pressure on the brake system under certain conditions of operation.

REC 10/04. It is recommended to the DGAC of Spain to encourage Iberia to take action to improve the communication channels between their different departments in a way that allows that flight crews and maintenance personnel may, at any time and from any airport, seek quick and effective engineering and operational support regarding situations not adequately covered by the manuals available to them.

REC 11/04. It is recommended to the DGAC of Spain to encourage Iberia to improve their methods of analysis of reports of abnormalities by the flight crews, consulting with the manufacturer when needed, in such a way that it is prevented the intermittent appearance of the same complaint, and that the useful information resulting from that analysis is provided to flight crews and maintenance personnel.

REC 12/04. It is recommended to the DGAC of Spain that the training methods provided to the applicable maintenance personnel of Iberia are monitored in order to assure that in the correction of the reports of intermittent malfunctions provided by flight crews, all the available maintenance documentation, as well as all the available clues, are used to analyse the causes of the malfunctions.

REC 13/04. It is recommended to Airbus that they should revise the content of the pertinent parts of the TSM in order to provide additional guidance regarding the maintenance procedures to be applied in the event of intermittent faults, taking into account the kind of fault and the available clues before dispatching again the aircraft. All operators should be informed on the results of that revision.

REC 14/04. It is recommended to Airbus that in the training they provide to maintenance personnel there is enough information to deal with intermittent failures.

REC 15/04. It is recommended to Airbus that it should be assured that the TSM and other specific or temporary maintenance documentation, like a «Technical Follow-up», is consistent and equally updated in regard to their technical content.

REC 16/04. It is recommended to the DGAC-France that the training syllabus recommended by Airbus to the airlines for type rating of A-340 is reviewed in order to assure that it leads to an adequate understanding of the details of the brake system of the aircraft.

REC 17/04. It is recommended to the DGAC-Spain that the training syllabus used by Iberia for initial type rating of flight crews in Airbus A-340 is reviewed to assure that enough time is devoted to reach an adequate understanding of the details of the aircraft brake system. This review should take into account any possible change in the Airbus recommended syllabus.

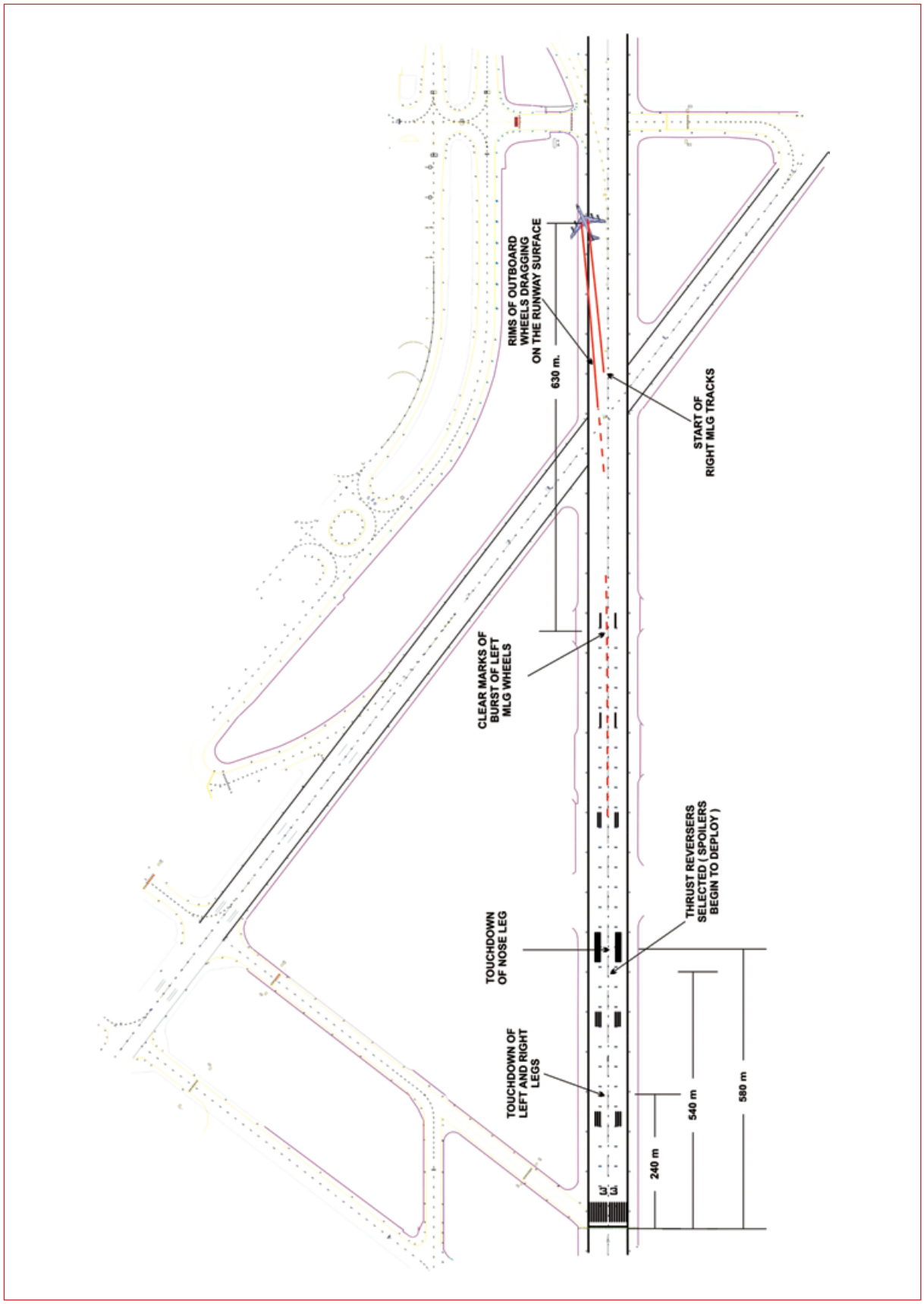
REC 18/04. It is recommended to Airbus that the content of the Abnormal Procedures and Supplementary Techniques of the A-340 FCOM are revised to unify the criteria of actions to be taken when the caution «Brakes residual braking» is displayed on ground.

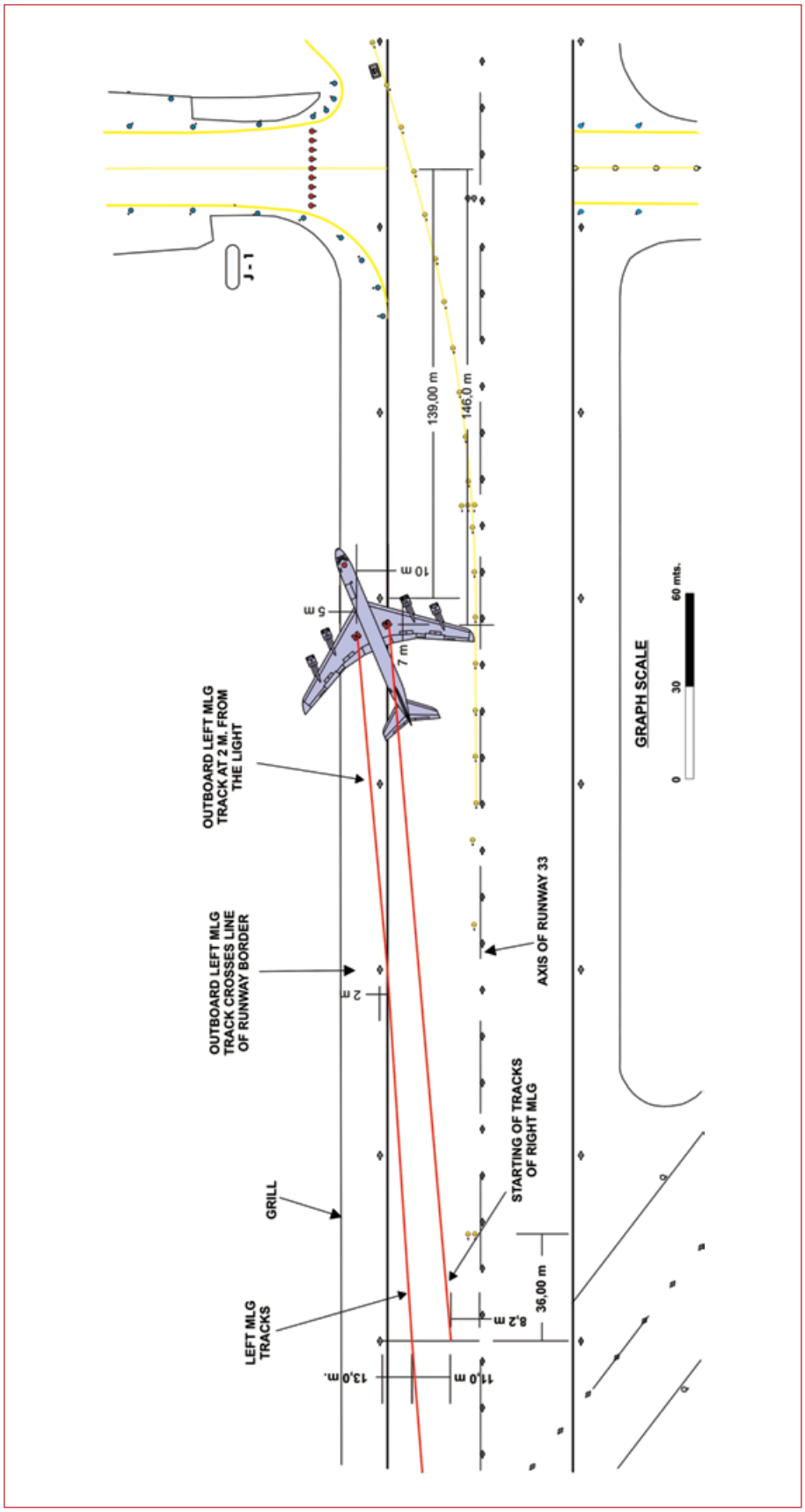
REC 19/04. It is recommended to Iberia that their Operations Manual of the A-340 is updated with the guidelines provided by Airbus regarding the use of autobrake during landing and the actions to be taken when the caution «Brakes residual braking» is displayed on ground.

APPENDICES

APPENDIX A

Diagram of tracks on runway 33 of Madrid-Barajas Airport


RIMS OF OUTBOARD WHEELS DRAGGING ON THE RUNWAY SURFACE
630 m.
START OF RIGHT MLG TRACKS
CLEAR MARKS OF BURST OF LEFT MLG WHEELS
THRUST REVERSERS SELECTED (SPOILERS BEGIN TO DEPLOY)
TOUCHDOWN OF NOSE LEG
TOUCHDOWN OF LEFT AND RIGHT LEGS
240 m
540 m
580 m


J - 1
139,00 m
146,0 m
10 m
5 m
7 m
OUTBOARD LEFT MLG
TRACK AT 2 M. FROM
THE LIGHT
OUTBOARD LEFT MLG
TRACK CROSSES LINE
OF RUNWAY BORDER
2 m
AXIS OF RUNWAY 33
GRAPH SCALE
0
30
60 mts.
STARTING OF TRACKS
OF RIGHT MLG
GRILL
LEFT MLG
TRACKS
36,00 m
8,2 m
11,0 m
13,0 m.

APPENDIX B

Details of the trouble shooting procedure applied after the incident

(1 TO 4 ARE ITEMS TO PREPARE THE AIRCRAFT FOR THE PROCEDURE)

...

5. Check for pressure (LH & RH ALT brake) using the cockpit triple gauge.

If pressure remains, Go to (6)
If no pressure remains, Go to (8).

6. If RH ALT pressure, unscrew caps K on the BDDV (5403GG)
If LH ALT pressure, unscrew cap I on the BDDV (5403GG)
If the pressure remains on the triple gauge, replace the BDDV (5403GG)
If the pressure clears on the triple gauge, replace LH (5422GG) or RH (5423GG) master cylinders.

7. Repeat tests (5) & (6).

If the pressure remains, the Dual Shuttle Valve (5404GG) should be replaced.
If the pressure clears, a dimension check of brake pedal rigging is required.

A quick test is to measure the distance between centre lines of master cylinder mounting holes. They should be the same as each other and be within the range of 170+0.1/+0.05mm.

Note that no compression of the Master Cylinder should be required to mount it in position. (Further checks see AMM 32-43-12-000-801, Removal of the Cockpit Alternate Brake Master Cylinders).

8. Fully depress and then release LH & RH brake pedals.

If pressure remains on pedal release, Go to (6).
If pressure clears on pedal release, Go to (9).

9. Apply and release park brake.

If the pressure remains, the Dual Shuttle Valve (5404GG) should be replaced and test repeated. (AMM 32-43-14-400-801 Dual Shuttle Valve – Removal/Installation).

If the pressure clears on parking brake release, go to (10).

10. If residual braking cannot be reintroduced, the following modified low-pressure circuit bleeding procedure (AMM 32-43-00-870-801, replenishment of the Alternate Braking Control Reservoir) should be used to check for restrictions in the low-pressure circuit.

With all AIC systems depressurised, attach a bleed hose to the bleed valve of the alternate brake control reservoir (5424GG). Put the other end in a container to catch the fluid. Drain until no fluid flows.

Unscrew cap a port 'J' of the BDDV and attach a bleed adapter (as identified in the bleeding procedure). Measure the flow to the bleed container from port 'J' of the BDDV (5403GG) when supplying fluid at a pressure of up to 4 Bars.

NOTE: Once the bleed valve opening is set for the first the test on side J (WH side) it should remain in the same position for side K (RM side).
The supply flow and pressure set for the first the test on side J (L/H side) should remain in the same position for side K (RIH side).

Repeat the above, this time connecting the port K of BDDV (5403GG).

Compare the flow rate from the pipe into the container. If the flow rates from the two sides are different or are restricted, a blockage is suspected.

11. Detach the master cylinder with restricted flow from the pedal assembly. Carry out a flow rate check as in (10).

If flow rate does not increase to rate of the 'good' side, then the master cylinder should be replaced.
If flow rate increases to rate of the 'good' side, then the pedal assembly should be removed and re-rigged.

END OF THE PROCEDURE