INCIDENT

Aircraft Type and Registration:	Falcon 2000, CS-DFE
No & Type of Engines:	2 CFE 738-1-1B turbofan engines
Year of Manufacture:	2003
Date & Time (UTC):	11 November 2009 at 1259 hrs
Location:	Biggin Hill Airport, Kent
Type of Flight:	Maintenance
Persons on Board:	Crew - 3 Passengers - 3
Injuries:	Crew - None Passengers - None
Nature of Damage:	Fire damage to tyres, fuselage, landing gear and wing
Commander's Licence:	Airline Transport Pilot's Licence
Commander's Age:	37 years
Commander's Flying Experience:	4,152 hours (of which 575 were on type) Last 90 days - 30 hours Last 28 days - 5 hours
Information Source:	AAIB Field Investigation

Synopsis

The aircraft had been undergoing a technical investigation to identify the cause of a braking defect. A flight crew were requested by the on-site maintenance team to carry out high-speed taxi trials as part of the troubleshooting process. The crew conducted a series of seven accelerate/stop runs along the main runway, at gradually increasing reject speeds. At the commencement of the eighth run, the crew felt that a tyre had deflated and brought the aircraft to a stop. They were informed by ATC that there was a fire under the left wing; the crew and passengers then abandoned the aircraft safely. The fire was caused by damage to the brakes from excessive temperature, this released hydraulic fluid under pressure, which then ignited. Four Safety Recommendations have been made as a result of the investigation.

History of the flight

General

The crew of the aircraft, which comprised a commander, co-pilot and cabin attendant, travelled to the UK on 9 November 2009. They had been tasked to be available to collect CS-DFE from Biggin Hill Airport where it was undergoing maintenance. They would then crew the aircraft on whatever flight it was allocated. At this stage the crew members were unaware of the nature of the maintenance.

In the evening 10 November 2009, the commander received a text message from the operator notifying her to be at Biggin Hill Airport at 1130 hrs for a "miscellaneous activity" to include "high-speed taxi requested by maintenance department". The intended activity was not designated as an Operational Check Flight (OCF) or Test Flight (TF), which have specific meanings and requirements.

Incident manoeuvres

The crew arrived at Biggin Hill Airport at about 1100 hrs and the commander contacted the operator's Maintenance Control to establish the whereabouts of the aircraft and what was required. She was told that the aircraft was still at the maintenance organisation on the south side of the airport and that the maintenance team would brief her there.

On arrival at the maintenance organisation, the maintenance team were with the aircraft on the parking area ready for the test. The flight crew were briefed that the aircraft was reported as pulling to the left when the toe brakes were applied. The maintenance team had carried out low speed taxi tests and another flight crew had conducted tests up to 50 kt, as a result of which the left brake units had been changed with the right brake units to see if the problem still occurred. The maintenance team requested high-speed tests, which the crew agreed to but advised they would adopt an incremental approach starting at 50 kt and increasing to 80 kt.

The crew carried out performance calculations to ensure the runway length was adequate for the task to be performed. The main runway at Biggin Hill is orientated 03/21 and is 5910 ft long by 147 ft wide (Figure 1) and has a tarmac surface which was dry. They estimated that the balance field length required for an abandoned takeoff at V_1 for the weight and ambient conditions was 3,000 ft. The crew decided that it would be possible to carry out two low-speed runs, one after the other, in the full runway length available.

The commander then carried out a full crew briefing for the conduct of the trials which included the maintenance team. The three crew members boarded the aircraft, along with the maintenance supervisor and two technicians. The maintenance supervisor occupied the jump seat between the two pilots and the two technicians were seated in the rear of the passenger cabin. The cabin attendant gave a passenger brief to remind them of the main exits and wearing of seat belts.

Having completed the normal external and internal checks, the engines were started at 1226 hrs and the aircraft was cleared to taxi for Runway 21 at 1231 hrs, entering the runway at 1239 hrs.

The crew commenced a series of accelerate/stop runs along the runway by selecting takeoff thrust, accelerating to the target IAS, then retarding the thrust levers and applying the brakes positively, bringing the aircraft to a stop. The first two runs were up to 50 kt IAS using Runway 21 before turning around and performing two 60 kt runs along Runway 03. The aircraft cleared the runway at holding point A3, in order to allow another aircraft to depart, and then taxied back to the threshold of Runway 21. The aircraft was cleared to enter Runway 21 to commence the next taxi test at 1248 hrs. The aircraft was accelerated to 80 kt and the commander had to apply full left brake in order to keep the aircraft straight. A second run was carried out to 50 kt and this was normal in maintaining runway alignment, but as with the other runs, the anti-skid system was activating at the lower speeds.

The aircraft was turned around and another 80 kt run was carried out along Runway 03, but this time the aircraft veered to the left. The maintenance supervisor on the jump seat and the flight crew discussed the findings and it was agreed to carry out one more run

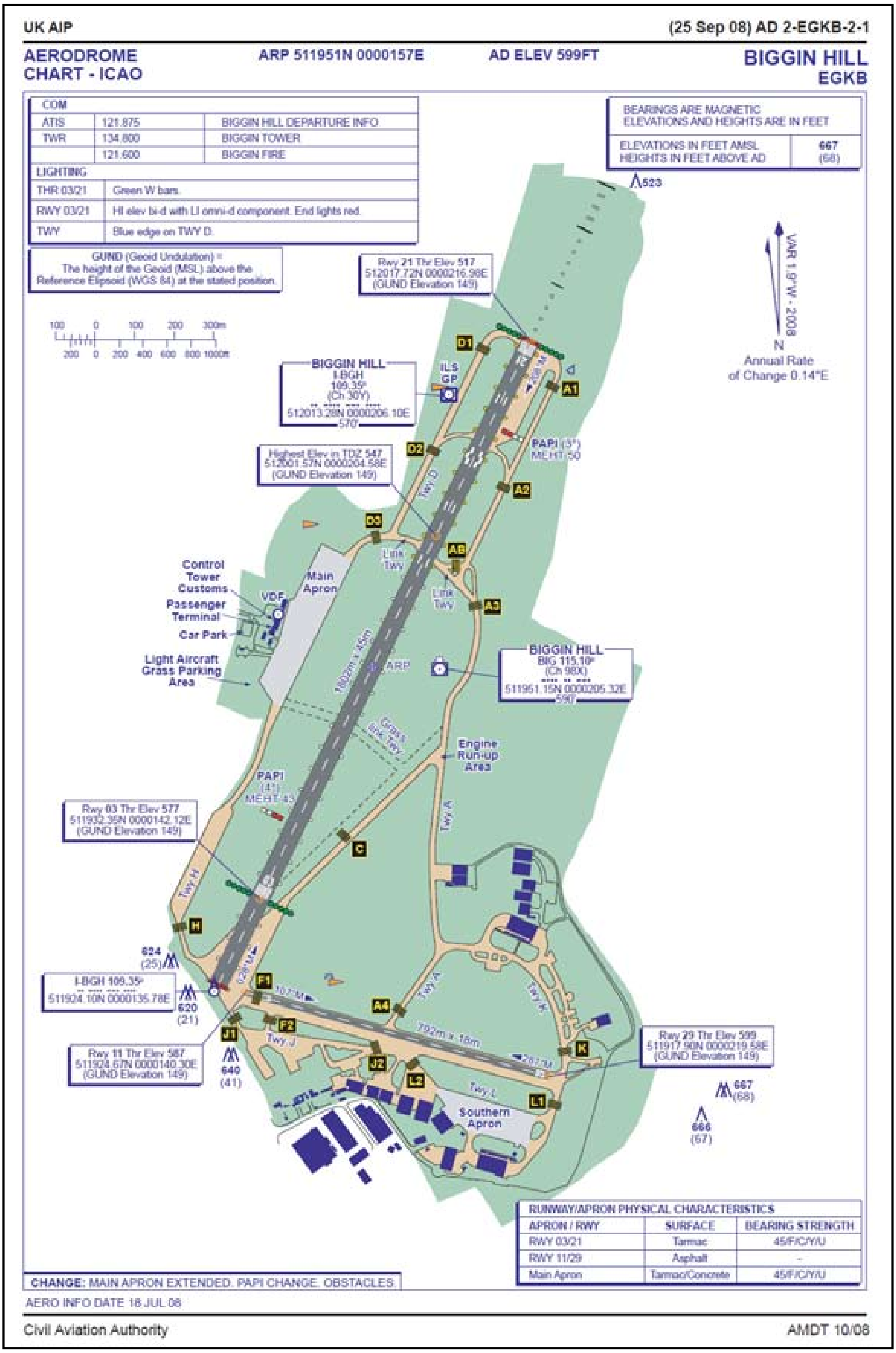

Figure 1

Biggin Hill airport layout

along Runway 21. The aircraft was taxied to the end of Runway 03 and turned around onto Runway 21 in order to perform another 80 kt test. The commander accelerated the aircraft, but before 30 kt, the test was abandoned as the crew believed they had a flat tyre on the left Main Landing Gear (MLG). They informed ATC and requested a tug, but shortly after, the pilot of another aircraft holding at D2 informed ATC that there was a fire on the left MLG of CS-DFE. ATC confirmed this visually and at 1257 hrs advised CS-DFE that there was a fire and to evacuate the aircraft. The crew carried out the evacuation drills and all those on board left the aircraft without difficulty through the normal airstair door. The Airport Fire and Rescue Service (AFRS) responded immediately and extinguished the fire.

Flight Recorders

The aircraft was fitted with a 25-hour Flight Data Recorder (FDR) and a 2-hour Cockpit Voice Recorder (CVR). These were both removed from the aircraft following the incident to be downloaded and then analysed by the AAIB.

The parameters recorded on the FDR were of limited value to the investigation; however, it was possible to determine the timing and maximum speed of each high-speed taxi run. The regulations at the time the aircraft type was first certified did not require brake pressures and temperatures to be recorded.

The salient FDR parameters are presented at Figure 2 and show that in total, eight high-speed taxi runs were completed over a period of just under 16 minutes. The first seven runs achieved speeds of between 60 kt and 90 kt. The final run was aborted at just over 35 kt[1] when the crew (verified on the CVR recording) realised that the aircraft had a flat tyre.

The duration of each of the runs was between 20 and 25 seconds. A number of runs were conducted one after the other on the same runway, with a gap of about 45 seconds between runs. Others required a change of runway which took between 90 and 200 seconds to complete.

Aircraft description

The Dassault Falcon 2000 is certified as a 19-seat, 16.5 tonne maximum takeoff weight business jet, powered by two turbofan engines. It is equipped with a retractable landing gear with two main gears and a nose gear. Each MLG is fitted with two wheels, radial tyres and hydraulically operated, carbon disk brake units. The aircraft is fitted with a wheel well overheat warning system, but there is no measurement or indication of brake temperatures. The aircraft has two main hydraulic systems, both of which supply the braking system (Figure 3).

Initial aircraft inspection

Prior to notification of the incident to the AAIB, the operator replaced the aircraft's mainwheels and tyres. The aircraft was towed clear of the runway and parked on an adjacent taxiway. The removed wheels, tyres and bearings were retained and made available to the investigation. All the tyres had deflated by way of the thermal fuses releasing and the sidewalls on both tyres from the left MLG had been partially consumed by fire.

An initial inspection of the aircraft was carried out on the taxiway which confirmed severe fire damage. A significant section of the lower skin of the left wing, rear of the landing gear bay, was burnt away, as was the

Footnote

[1] Airspeed is normally unreliable below 30-40 kt; however, a calculation of groundspeed, based on the acceleration of the aircraft, showed this figure of 35 kt to be accurate.

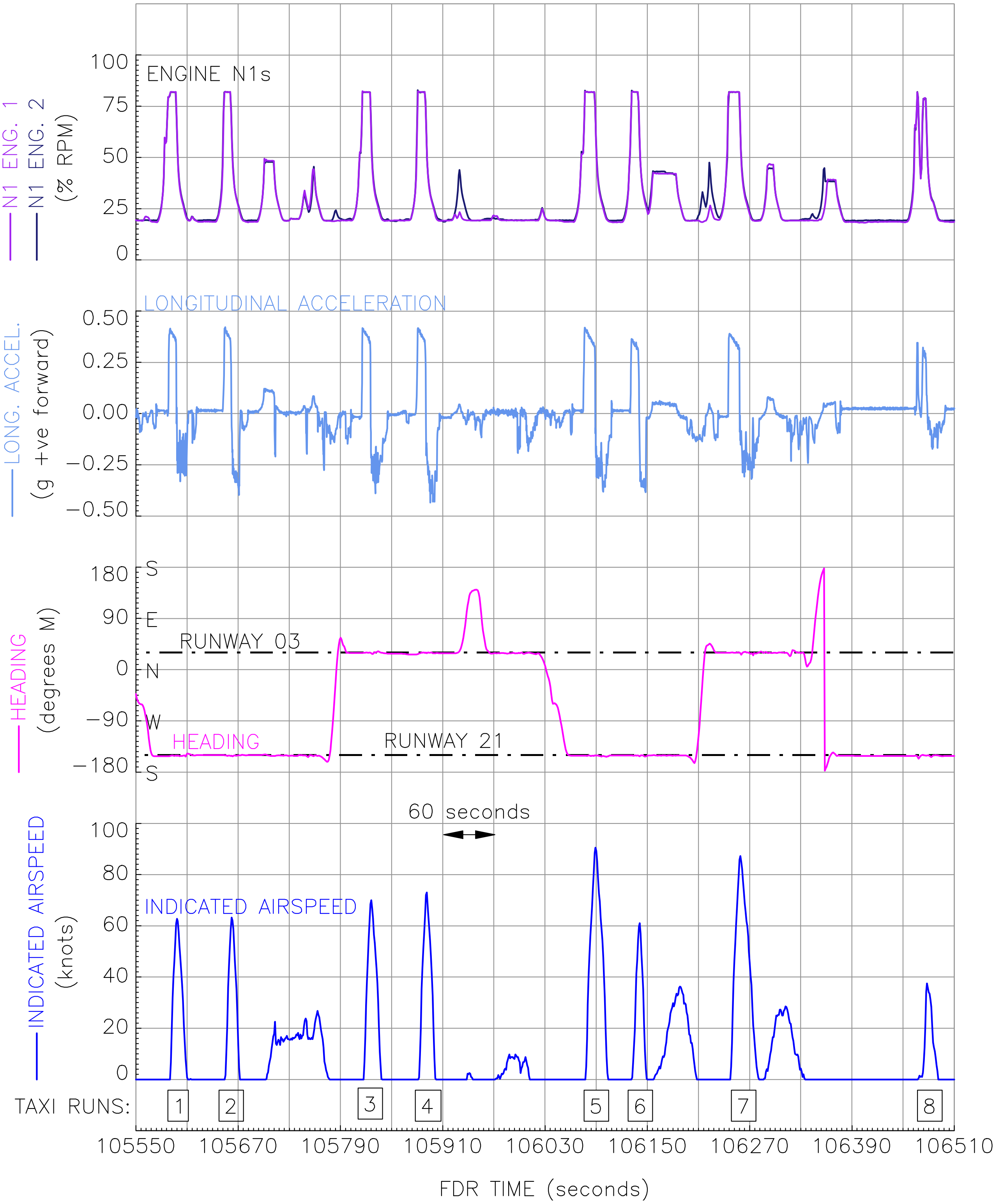

Figure 2

Salient FDR parameters from CS-DFE of high-speed taxi runs

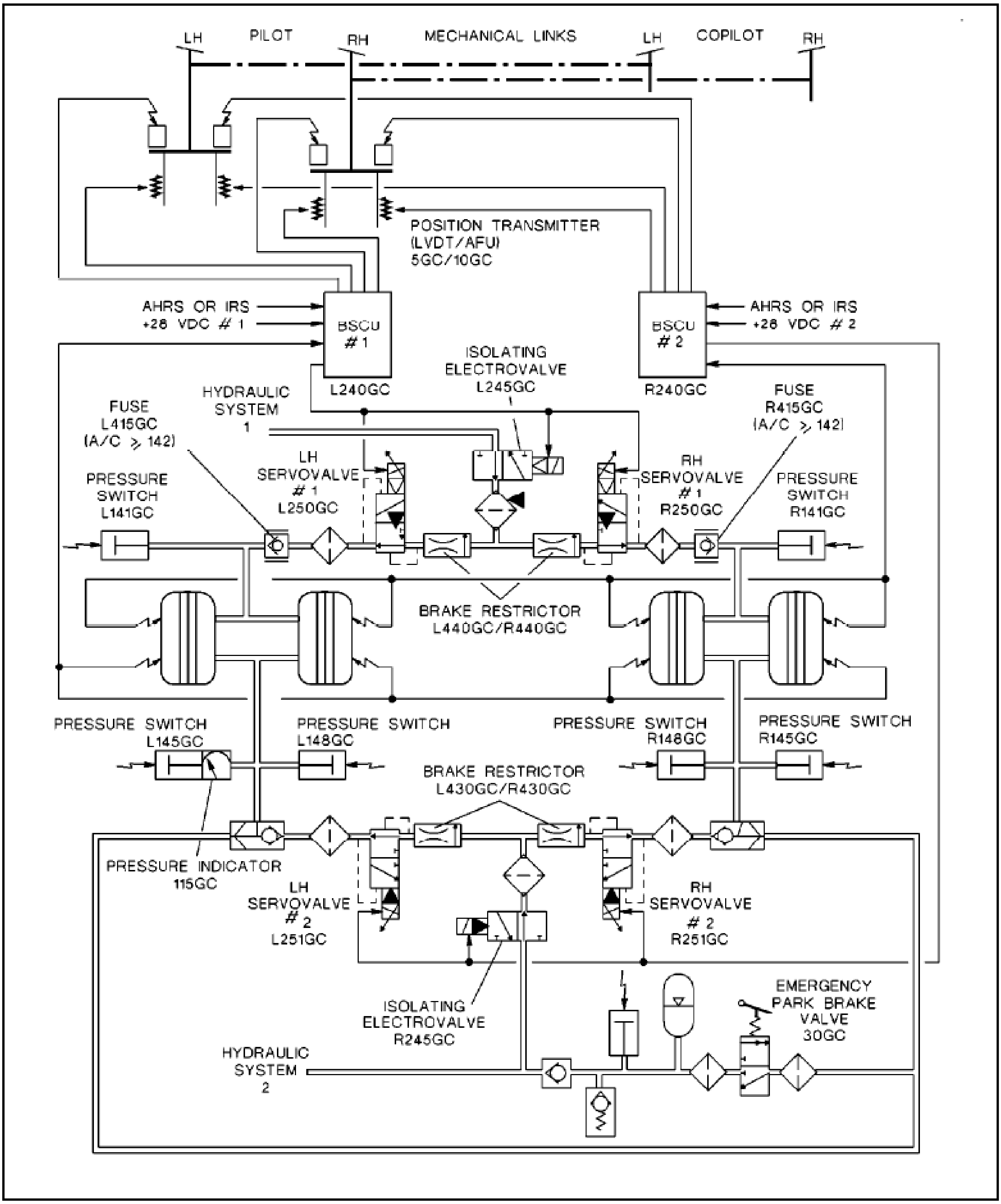

Figure 3

Aircraft braking system

lower skin of the adjacent flap, which had been partially deployed at the time (Figure 4). The landing gear bay within the wing was heavily sooted with extensive heat damage evident to the upper wing skin and the electrical wiring looms running along the rear of the wing. The fuselage panels adjacent to the left MLG bay were severely heat damaged and the whole of the fuselage, rear of the wings, was heavily sooted. The number two hydraulic system reservoir level indicator showed that the system contained no hydraulic fluid; the number one hydraulic system reservoir was indicating just over half full. There was no evidence of fire around the right MLG.

Detailed aircraft inspection

The aircraft was recovered to a hangar for detailed inspection of the damage.

Left main landing gear

The MLG leg displayed extensive heat damage and sooting. The wiring looms located on the leg were significantly charred and fire damaged. The hydraulic pipe work attached to the MLG leg was also severely heat damaged. The coating on both the brake units had changed from silver to dull bronze indicating that they had been subjected to temperatures in excess

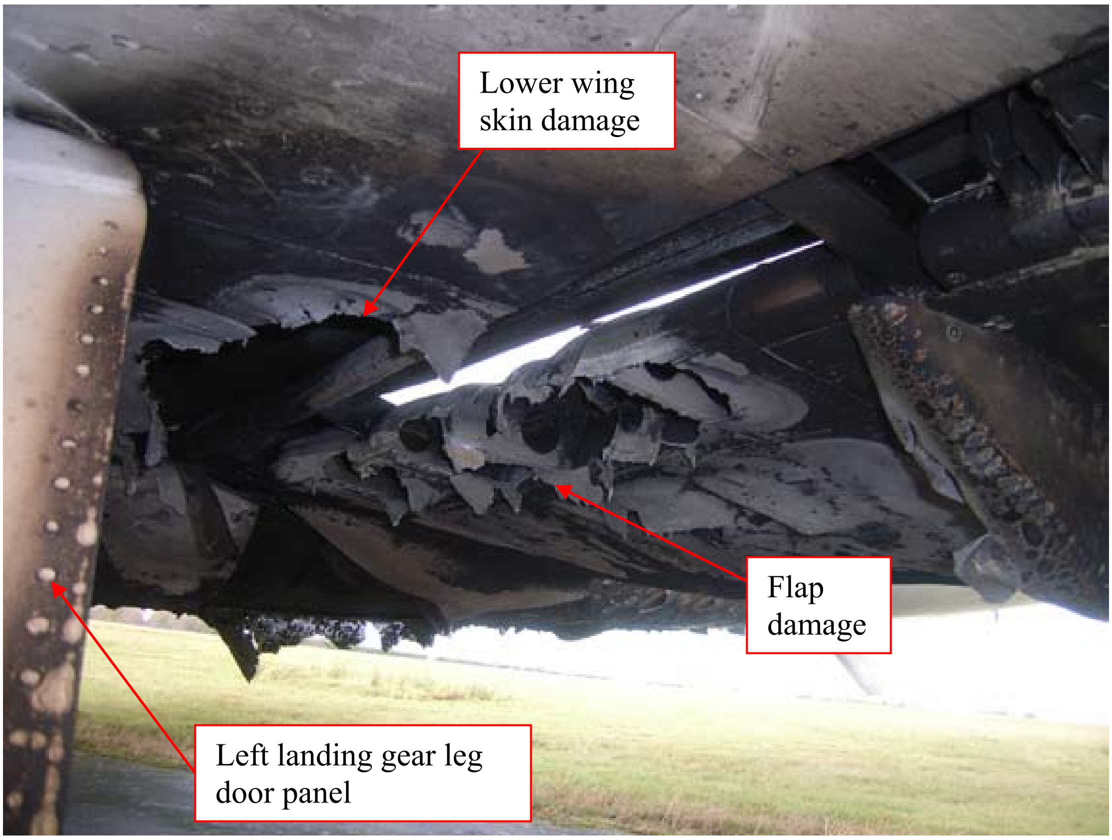

Figure 4

Lower wing skin and flap fire damage

of 150°C. The cadmium coating on the left MLG axles had blistered suggesting temperatures in excess of 400°C. The hydraulic system pipes between the servo valve and the brake units were refilled with fluid and pressurised using a hand pump. Fluid leaks were identified in the flexible hoses at the base of the MLG leg as they joined the brake unit and in the brake unit pistons.

Right main landing gear

No evidence of fire was found on the MLG, however, the coating on the number three brake unit housing (inboard wheel of the pair) had also changed from silver to bronze. The hydraulic system pipes were also filled and pressurised and leaks were identified around the number three brake unit pistons.

Brake unit inspection

Both the left MLG brake units and the number three brake unit from the right MLG were removed and sent for disassembly and inspection at the manufacturer's overhaul facilities.

The inspection found that all three units displayed severe heat damage after experiencing 'exceptionally' high brake energies. The elastomeric static and dynamic piston seals were completely destroyed (seal degradation would have started at a temperature of 183°C). The aluminium alloy housings within the brake piston assembly had melted, indicating temperatures in excess of 200°C and the pistons themselves were significantly deformed (Figure 5). The protective coating on the carbon discs had been removed indicating temperatures in excess of 1,200°C.

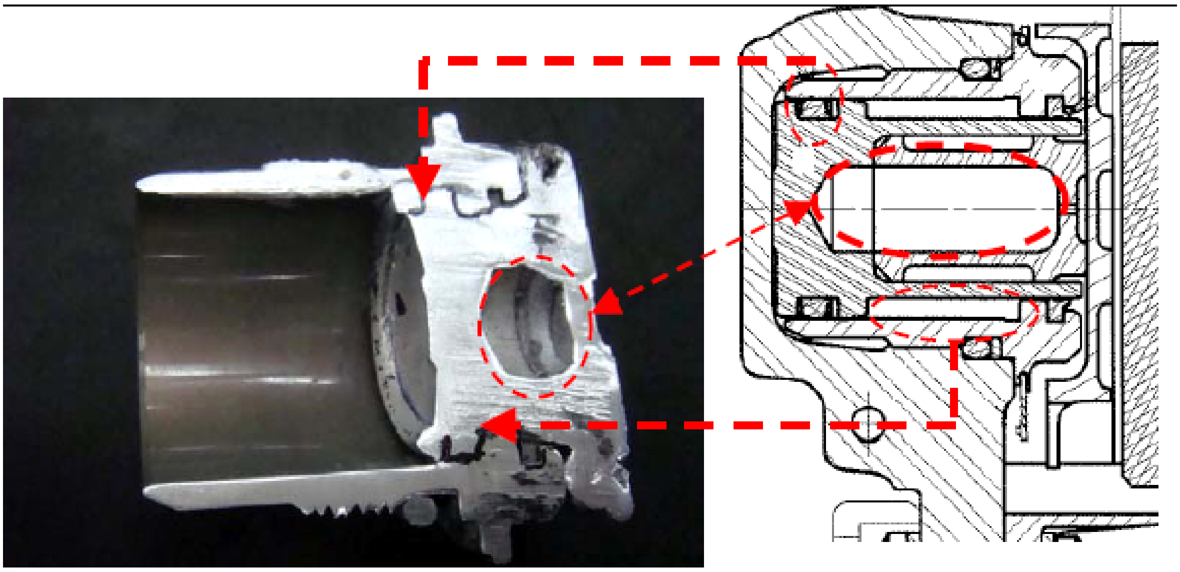

Figure 5

Brake piston deformation

Brake energy calculation

Using the recorded flight data, the manufacturer assessed that each of the left brakes had absorbed just under 18 MJ of energy and each of the right brakes just over 11 MJ[2] from the cumulative effect of eight braked runs conducted during the incident.[3] During certification the brakes had been tested up to 15 MJ on the aircraft and 16.4 MJ during brake qualification tests. Based on the data obtained from development testing with a fully worn heat sink, 16 MJ of brake energy was assessed to elevate the brake temperature by approximately 1,600°C.

The wheel fuse plugs are designed to melt at 199°C. It was assessed that the level of brake energy which would result in the wheel thermal fuses releasing was achieved during run five for the left brakes. Maximum energy rejected takeoff tests during aircraft certification showed that a period of five minutes or more, after the point where sufficient brake energy is achieved, could be required, depending on ambient conditions, for the heat to transfer from the brake unit to the area where the wheel thermal fuses are positioned. The incident was consistent with this experience, as the tyres started to deflate prior to run eight, some five and a half minutes later.

Brake life

The number one and two brakes had achieved 786.6 hours and 535 cycles. The number 3 brake unit had 642.8 hours, 403 cycles and the number four unit 453.1 hours and 310 cycles. The average number of cycles achieved by a Falcon 2000 brake unit prior to removal is 1,100.

Footnote

2 During run five the handling pilot applied only the left brake pedal, thus retarding the aircraft using the left brakes only. Brake energies were calculated based on an estimated aircraft weight of 25,674 lbs.

3 Whilst these calculations required a number of assumptions to be made and therefore may underestimate the actual energy levels experienced, it is unlikely that the estimates vary sufficiently to affect the relative exceedence or otherwise of the approved limit.

Hydraulic fuses

In 1999 a Falcon 2000 aircraft experienced a total loss of hydraulic fluid event. This was a result of foreign object damage to a bracket on the MLG that supported the brake hydraulic hose connections for both systems. As a consequence of this incident the No 1 hydraulic system was modified to include fuses which isolate the MLG hydraulic fluid pipes when an excessive flow rate is detected. The manufacturer did not apply the modification to the No 2 system due to the lack of service experience of the fuses on Falcon aircraft and to avoid the risks associated in modifying both systems with the same design change simultaneously. The fuses successfully activated during this event retaining a significant amount of fluid in the No 1 system. As there were no fuses fitted in the No 2 system, the entire fluid contents was lost through the leak paths identified in the brake pistons and supply pipes.

A sustained fire resulting from an uncontrolled loss of hydraulic fluid has been identified as a significant risk by airworthiness authorities for many years and has been addressed by the introduction of specific wording within the design regulations. The current amendment (8) of CS 25, paragraph 25.735 states:

> *'(b) Brake system capability.*
>
> *The brake system, associated systems and components must be designed and constructed so that:*
>
> > *(2) Fluid lost from a brake hydraulic system following a failure in, or in the vicinity of, the brakes is insufficient to cause or support a hazardous fire on the ground or in flight.'*

The aircraft was certified to JAR 25 Amendment 13, which did not include the wording of paragraph (b). However, the intent was still present within the requirement, as the guidance material in the ACJ issued for compliance with 25.735 at the time stated:

> ***'Protection against fire***
>
> *Unless it can be shown that hydraulic fluid which may be spilt on to hot brakes is unlikely to catch fire, the hydraulic system should be protected so as to limit the loss of fluid in the event of a serious leak. The precautions taken in the latter case should be such that the amount of fluid lost in the vicinity of the brakes is not sufficient to support a fire which is likely to hazard the aeroplane on the ground or in flight.'*

The manufacturer provided the following response when this was discussed with them:

> "During the event, the braking energy absorbed by the brakes of the F2000 205 is much higher than the maximum certified energy: The document DGT 341504[4], which estimated the absorbed braking energy, shows an energy of 17.9 MJ per brake. Furthermore, the energy was absorbed by 8 RTO [Rejected TakeOffs] performed along 15 minutes. This scenario is very different from the usual single RTO were [sic] the energy is absorbed in less than 1 minute. The longer duration in the case of the event has lead to more heat diffusion from the heat pack to the torque tube and hydraulic housing which explains the important deformation of pistons, seal pistons destruction and consequently leakage from pistons towards the heat pack. In the case of the F2000 205, we consider that the fire on ground did not lead to a hazardous situation as it did not jeopardize the aircraft evacuation."

Operator's Operations Manual

The operator's Operations Manual (OM) Part A, contains the relevant information with regards to TFs. The text is set out below:

> ***'8.7.1.4 Test Flights***
>
> ***8.7.1.4.1 Reason for Test Flights***
>
> *A test flight must be performed after special maintenance and/or repair work on an aeroplane and on special request of the authority.*
>
> ***8.7.1.4.2 Test Flight Programmes***
>
> *Test flights shall be performed in according to programmes issued by the responsible technical department, in agreement with the flight operations department.*
>
> ***8.7.1.4.3 Test Flight Crew***
>
> *Those flights shall be performed by the minimum flight crew according to AOM. Only experienced pilots should be assigned by flight operations for test flights.*
>
> ***8.7.1.4.4 Other Crew***
>
> *If it is required by the nature of the test flight, there may be, in addition to the minimum crew, engineers, mechanics or inspectors on board who were directly involved in the preceding work/inspection of the aeroplane. They must be recorded in the flight log as additional crew members.*

Footnote

4 This refers to a document supplied by the manufacturer which detailed the calculated brake energy based on recorded flight data.

> ***8.7.1.4.5 Briefing***
>
> *The responsible engineer shall give the flight crew a briefing on:*
>
> - *The reason for the test flight;*
> - *The test programme; and*
> - *How the preceding work may influence the airworthiness of the aeroplane.*
>
> ***8.7.1.4.6 OCF (Operational Check Flight)***
>
> *An OCF is a flight where one or more aircraft systems need to be checked for proper operational functioning. No passengers can be carried on OCFs except for crew members and maintenance engineers required for observation.*
>
> ***8.7.1.4.7 Conditions Requiring an OCF***
>
> - *Engine maintenance*
> - *Flight control maintenance*
> - *Pressurisation maintenance*
> - *Landing gear maintenance after a failure of the landing gear to extend or retract*
> - *When required after phase inspections*
> - *When so required by the maintenance and/ or Flight Operations Department'*

The OM provided information regarding weather, runway and performance requirements all of which were complied with on the incident flight. The OM specifies the operating crew requirements.

> ***'8.7.1.4.10 Operating Crew Requirements***
>
> *None of the operating crew may be inexperienced (as defined in paragraph 4.1.5 or on training except during PIC line training.*
>
> *Any PIC with less than 500 hours on type requires FM/AFM (Fleet Manager/Assistant Fleet Manager) approval.'*

The definition of inexperienced is found at paragraph 4.2.2 which is set out below.

> ***'4.2.2 Crewing of Inexperienced Flight Crew Members***
>
> *A flight crew member is considered inexperienced, following completion of a type rating or command course and the associated line training, until he has achieved 100 hours and/or 30 sectors on the type.'*

The operator had set out a procedure for flight crew to become qualified to carry out an Operational Check Flight (OCF). It was contained in the company Flight Operations Procedures, NJFOP 1.02 '*OCF Pilot Qualifications Procedure'*, extracts of which are set out below:

> *'The respective Fleet Manager invites interested pilots to submit a brief description of relevant factors. Interested pilots are then assessed based on, but not limited to, technical background, experience and any other additional roles. If selected, pilots are then shortlisted to undergo OCF training.'*

The procedure sets out the method of training which is a briefing by the Fleet Manager covering a comprehensive range of subjects set out in the document and self study by the pilot. On successful completion of the training, the pilot's name and qualification are entered into the electronic crew scheduling system.

The operator had differentiated between OCF and TF. The OCF is "a flight used to verify component/ system/ or aircraft performance to determine correct operation after maintenance" while a TF is performed to "verify component/ system/ or aircraft performance to determine certification". Whilst the operator had defined the OCF and TF, as well as the crew composition and qualification to conduct the flights, the brake test troubleshooting taxi runs had not been placed into either category.

Aircraft manuals

The Approved Maintenance Manual (AMM) for the Falcon 2000 does not specify taxi trials to be conducted as part of any defect troubleshooting activity. There is no test schedule published by the manufacturer in any of the aircraft manuals for conducting the kind of braking tests attempted by the operator. As such, there was no specific guidance regarding cumulative brake energies and brake cooling times. The Airplane Flight Manual (AFM) does, however, have three sections which can be considered relevant:

1) Within the limitations section of the AFM, under the section heading '*Tires and Brakes*' the following limitation is published:

> *'Brake kinetic energy limit: 15,000 kJ per brake'*

2) Within the performance section of the AFM, graphs are provided showing how the maximum brake energy speed in takeoff configuration varies for a range of parameters such as ambient temperature, pressure altitude and takeoff weight. This allows the pilot to calculate, for the prevalent conditions, the speed from which the braking effort in the event of a rejected takeoff would result in the maximum brake energy being achieved. When the combination of the various parameters present on the day of the incident was assessed, the chart showed that the calculated maximum brake energy speed was off the scale of the graph, well in excess of the 160 KIAS highest value.

3) Within the AFM performance section is guidance on minimum turnaround time. This includes graphs for calculating brake energy and brake cooling times following a rejected takeoff or landing. The charts themselves require a degree of interpretation and cannot be used in the 'quick reference' style of a checklist. An example calculation is also provided in this section of the manual to assist in understanding the use of the graphs. It uses the scenario of two sequential rejected takeoffs with a period of taxiing between.

The start of this AFM section on minimum turnaround time explains the way in which brake energy and cooling time is calculated from the graphs. It explains that energy from a previous RTO or landing should be calculated, an approximate energy figure to take account of further taxiing should be added to this and then the energy of a further RTO at V_1 added. The manual then states:

> *'If the sum of the energies absorbed per brake is below 12.09 x 10^6 ft.lb (16.4 MJ), no cooling time is required.'*

This quoted figure of 16.4 MJ exceeds the brake energy limitation of 15 MJ that is stated in the limitations section of the AFM. Also, a note in these charts states that energies of 10.6 MJ (new brake) and 9.5 MJ (worn brake) will cause the wheel thermal fuses to '*blow*'.

The aircraft manufacturer advised that the maximum energy of 15 MJ quoted in the AFM was demonstrated with an initial heat sink temperature of 246°C, which is equivalent to 16.4 MJ given an initial temperature of 20°C. Therefore, 16.4 MJ was the qualification maximum energy demonstrated during bench testing by the brake manufacturer.

15 MJ per brake was the maximum energy demonstrated during the maximum energy RTO certification test and hence was used for the limitation, but benefit of the 16.4 MJ figure was taken for the determination of the minimum turnaround time.

Although not directly applicable to the tests conducted prior to the incident, the AFM would have provided an approximate figure for brake energy and the appropriate cooling times to remain below the published limit. The operating crew during the incident reported that they were unaware of any limitations and had not consulted this section of the AFM prior to embarking on the tests.

Flight crew training

During the type rating raining for the Falcon 2000, the use of the '*Minimum Turnaround Time*' subsection of the performance section of the AFM was included in the course. The commander recalled that during the flight phase of her training, whilst carrying out circuits and roller landings, she had been told that brake energy was not a problem on the Falcon 2000.

Operator/Maintenance actions prior to the event

The aircraft flew into Biggin Hill on 1 November 2009. The commander recorded a defect in the aircraft technical log stating:

> *'A/c pulls left with even application of the brakes. Evident from both pilots brake pedals and through emeg. brake. Problem is worse as brakes heat up, therefore not noticeable on pre flight brake check.'*

A work package was raised by the operator's maintenance provider on 2 November 2009 and a maintenance supervisor and two technicians were despatched from their base at Northolt the same day to troubleshoot the defect on the aircraft.

Initially, the aircraft was raised on jacks and an inspection of the wheels carried out; this determined that they were free to rotate and there were no obvious defects. The maintenance team then taxied the aircraft at low speed along Runway 03, and whilst applying the brakes at speeds of between 5 and 10 kt they reproduced the pull to the left. These tests were eventually abandoned due to a suspected flat tyre. An inspection confirmed that this was not the case, but the left MLG tyres had extensive flat spots and large skid marks had been left on the runway surface, predominantly from the left MLG, but occasionally from the right.

The left wheels (No 1 and No 2) were replaced and the Brake System Control Units (BSCU) were interchanged. However, further low speed taxi trials confirmed the defect was still present along with a number of fault codes on the BSCU. At this point the manufacturer's helpdesk was contacted and after consultation, the No 1 and No 2 tachometers were replaced. Based on guidance provided by the helpdesk, the aircraft was then subjected to further rig checks, including brake function using a hydraulic rig and a function check of the anti-skid system; no defects could be identified. Further low speed taxi trials were conducted during which the defect was not present. The maintenance team reported that as the helpdesk could provide no further troubleshooting guidance, they requested a flight crew to carry out high-speed taxi trials to assess whether the defect reoccurred as the brakes heated up.

Correspondence with the manufacturer's help desk showed that the manufacturer was aware that high-speed taxi trials were being proposed and were to be conducted by the operator and their maintenance team, although as the content of these trials was not decided until the day of the test, they would not have been aware of any specific details. The help desk staff also suggested, in email correspondence, that taxi trials were necessary to prove the defect had been cleared, although the nature of any such trial was not elaborated on.

A flight crew arrived on 6 November 2009 and they conducted a number of RTO stops, which showed that the aircraft still pulled to the left and that the anti-skid was active as the aircraft decelerated from 40 to 20 kt IAS. The maintenance team returned to the aircraft on 9 November 2009 and were instructed by the operator's maintenance manager to interchange the brake units from position 1 to position 3 and from 2 to 4. This work was completed and a further high-speed taxi test was scheduled for 11 November 2009. Hydraulic leak checks, system function checks and general walk round inspections were performed prior to the day of the taxi trial, which did not identify any issues or leaks.

As laid out in the history of the flight section of this report, the crew which arrived to conduct the maintenance tests were not aware of the history of the problem and were told that a full brief would be provided by the maintenance supervisor on-site. When interviewed after the event, the maintenance supervisor reported that he believed he could hand the aircraft over to the crew and they would carry out the taxi trials in accordance with their own procedures. The maintenance team opted to be in the aircraft during the trials for the experience, but did not consider it their role to influence the way in which the test was conducted. Following further discussion between the commander and the maintenance supervisor, a rough plan to conduct a series of RTO stops along the runway at gradually increasing reject speeds was agreed between the crew. However, no formal test schedule was written and no pre-test assessment of the potential risks or actions in the event of a problem were considered. The maintenance supervisor sat directly behind the crew during the test, but did not wear a headset. This was the first time he had been present in the aircraft for any form of high-speed taxiing or braking tests.

Engineering organisation, management procedures and oversight

The operator's headquarters were based in Portugal. Due to the nature of their operation, this was an administrative hub representing the Part M organisation only, with maintenance subcontracted to a number of Part 145 approved Maintenance Repair Organisations (MRO) at locations around Europe. These MROs operated to a set of procedures issued by the operator, who regularly audited their compliance. The UK based MRO was a wholly owned subsidiary of the parent company of the operator and worked exclusively on the operator's aircraft, though they were still tasked with work requests in the same manner as the other MROs. Operational control of aircraft, flights, crewing and maintenance was done by means of a computer based system called I Jet. This allowed the location of the aircraft to be tracked, maintenance inputs, flights and operating crew to be scheduled and also identified the aircraft's serviceability status. It was linked to maintenance, such that outstanding work packages had to be signed off as complete before the status could be updated and the aircraft released to operate. Only the operator could amend the status of the aircraft on the system. The request from the maintenance team for high-speed taxi trials was forwarded by the MRO's maintenance manager to the operator's duty maintenance manager, who authorised the test and requested the crew scheduling team to allocate a crew. He did not discuss the requirement with the flight operations duty fleet manager and had not considered that any specialist crew would be required. The crew were allocated and their names were entered into the I Jet management system. Had the tests required the aircraft to be released for flight, the open status of the work package may have prompted the test to be classified as an Operational Check Flight (OCF) and the appropriate flight crew allocated, as the aircraft status was still 'undergoing maintenance'; this did not take place.

In addition to the top level flight crew requirements for OCF and TF in Part A of the operator's Operations Manual, specific instructions at a working level were published by the operator in a procedure called NJMP 1.15. A copy of this procedure was available in the aircraft's onboard technical document library, as well as at the headquarters where the duty maintenance manager was based. It listed a number of requirements relating to allocation of flight crew, pre-test paperwork and briefings and post-test debriefing and recording of findings. There were no procedures in place to document the roles of either of the maintenance managers involved and no guidance as to when procedure NJMP 1.15 became applicable. However, based on custom and practice the operator's maintenance manager would decide when to apply NJMP 1.15 and request an OCF qualified flight crew as necessary. In this case he did not consider the check flight procedure was applicable to high-speed taxi test activity, as the tests were only for the purpose of maintenance defect troubleshooting on the ground.

Safety action

The operator's safety investigation highlighted concerns about the lack of procedures to cover the engineering and operations interface regarding aircraft test activity. In response to this, procedure NJMP 1.15 was amended to cover high-speed taxi trials and engine ground runs. The Operations Manual was also updated.

Analysis

Flight crew

The crew were properly licensed and qualified to operate the aircraft. Whilst the commander had met the 500 hours on type minimum requirement for OCFs, she had not carried out the training to conduct an OCF and was not included as such on the I Jet system. The high-speed taxi trials had not been identified as an OCF and no test schedule was available.

Following the briefing by the maintenance supervisor, the flight crew carried out a risk assessment of the test activity. They considered the greatest hazard was overrunning the end of the runway whilst carrying out the accelerate/stop manoeuvre. This was addressed by carrying out the appropriate performance calculations. By incrementally increasing the target speed for stopping the aircraft they also addressed the possibility of significant lateral departure from the runway centreline. However, the risks associated with exceeding the brake energy limit were not identified by the crew or the maintenance team.

The composition of those persons onboard was not governed by the requirements of a TF or an OCF which would probably have required only the maintenance supervisor being present in addition to the minimum flight crew of the two pilots. On the incident flight, two technicians were also present and for this reason the cabin attendant also boarded the aircraft.

On the final manoeuvre, when the crew suspected that they had a deflated tyre on the left MLG they stopped the aircraft on the runway in order to assess the situation. At this stage, they received the information regarding the fire and carried out the emergency evacuation drill which concluded in the safe evacuation of all those onboard.

Aircraft fire

Whilst attempting to troubleshoot a braking defect, the crew conducted eight high speed rejected takeoffs, within a 15 minute period, with limited distance travelled at taxiing speeds and no significant periods of cooling between runs. The cumulative effect of this was to subject the left gear brake units to energy levels in excess of what they were designed to accommodate and the certified limits demonstrated during aircraft development. This raised the temperature of the brake components to the point where the hydraulic fluid seals failed and significant structural damage occurred. Consequently, hydraulic fluid was released at high pressure which rapidly ignited on the hot brake surfaces, resulting in a sustained fire around the left MLG.

The crew were not aware of the fire until another aircraft crew in the vicinity relayed a warning to the air traffic controller, who in turn advised the crew to abandon the aircraft. Consequently, they were able to evacuate the occupants safely, whilst a rapid response by the professional and fully equipped AFRS allowed the fire to be brought under control.

The extent and duration of the fire and the associated level of damage were directly attributable to the amount of hydraulic fluid which was lost from the hydraulic systems. The No 1 hydraulic system was fitted with fuses which activated to limit the loss of fluid from this system. Had the No 2 system also been fitted with similar protection, the amount of fluid loss would have been reduced, with an associated reduction in the duration and severity of the fire.

The leak was caused by operation of the aircraft beyond its approved limits, which is an issue that cannot necessarily be mitigated by the manufacturer. However, the subsequent events demonstrated that regardless of the cause, the current design allows an uncontrolled loss of hydraulic fluid from the No 2 system, which will result in a significant and sustained fire when in the proximity of an ignition source, such as hot brakes. It should also be noted that the right main gear No 3 brake unit was leaking hydraulic fluid despite having potentially absorbed an energy level well within the approved limits. The risk from leaking hydraulic fluid was acknowledged by the airworthiness authorities prior to certification of the Falcon 2000 and although the aircraft was certified to JAR 25 Amendment 13, without protection to limit the loss of hydraulic fluid from a leak, the circumstances of this incident have highlighted that this represents a safety risk. Therefore, the following Safety Recommendation is made:

Safety Recommendation 2010-061

It is recommended that the European Aviation Safety Agency review the Falcon 2000 landing gear and hydraulic system design with a view to ensuring that, in the event of a leak, the system is protected so as to limit the loss of fluid in the vicinity of the brakes.

Systemic contributory factors

There were numerous systemic factors relating to the manner in which the operator conducted this test activity which contributed to the incident. Many of these, such as appropriate crew selection, the need for an approved test schedule and a detailed brief and debrief of the test activity with all involved personnel, are common to other recent incidents and accidents involving operators conducting maintenance or customer demonstration check flights. These issues have been highlighted and analysed in detail in the AAIB report into a serious incident involving a B737, G-EZJK, in the UK (reference: EW/C2009/01/02 AAIB Bulletin 9/2010) and a Bureau d'Enquêtes et d'Analyses (BEA) report into a fatal accident involving an A320, D-AXLA, in Perpignan, France (Report d-la081127). Recommendations to address these issues have already been made in the referenced reports and are equally applicable to conducting high-speed taxi trials; as such they are not repeated in this report.

Test preparation

Whilst the crew had been shown the brake energy graphs and calculations during their type conversions, they had not used them since. The brake energy limit is rarely encountered during normal aircraft operation, which may have reinforced an understanding by both pilots that brake energy was not a concern under any circumstances and they did not recognise the cumulative effect of carrying out multiple accelerate/stop manoeuvres.

A 'flight-test' schedule would have provided structure to the activity and an opportunity for a more formal risk assessment to be conducted. This would have addressed the runway overrun and lateral runway departure issues as well as the brake energy implications. Whilst the crew might have consulted the brake energy information in the flight manual, the manufacturer emphasised that the information derived was not appropriate for the purposes of this test activity.

AFM limitations and guidance

The use of different brake energy limitation figures within different chapters of the AFM is ambiguous and confusing. Minimum turn-around time guidance should reflect the maximum brake energy limit, which has been qualified by aircraft certification testing. The No 3 brake unit on the right MLG also exhibited significant damage and was leaking hydraulic fluid, despite apparently being subject to energy levels lower than both of the quoted limitations. The following Safety Recommendation is made:

Safety Recommendation 2010-062

It is recommended that the European Aviation Safety Agency require Dassault Aviation to review and amend the Falcon 2000 Airplane Flight Manual to ensure that the brake energy limitations quoted in all sections of the manual are consistent and reflect what has been satisfactorily demonstrated on the aircraft as a safe limit.

Even for normal operations, the AFM is unclear about the mitigating actions required by the crew in the event of high brake energies being encountered, particularly given the wheel fuse plugs are set to release significantly below the published brake energy limit. This means there is a likelihood that the plugs will release and the tyres deflate, regardless of brake performance. Clear and unambiguous guidance for the operating crew is particularly important given the lack of brake temperature indication or a brake overheat warning system[5]. Therefore, the following Safety Recommendation is made:

Safety Recommendation 2010-063

It is recommended that the European Aviation Safety Agency require Dassault Aviation to review and amend the Falcon 2000 Airplane Flight Manual to ensure that the guidance provided to flight crews relating to accumulated brake energy and minimum turnaround times is clear, consistent and takes account of all aspects of the aircraft's operation.

Maintenance

From a maintenance perspective there were a number of significant contributory factors. The practice of operating an aircraft with a significant problem for the purpose of replicating the defect can be a high-risk maintenance activity and as such it should only be considered once all other appropriate troubleshooting options have been exhausted.

If operational aircraft testing becomes necessary, then the risks need to be identified and addressed to ensure the tests are completed safely. One possible means of reducing risk would have been the use of a test procedure, or AMM task, approved by the manufacturer. In this case high-speed taxi trials were not a recognised AMM test and no additional guidance was sought from or offered by the manufacturer in support of the test activity.

The operator's maintenance manager had approved the request for the aircraft trial to take place. However, there was a lack of clear procedures or guidance available to advise him of his role and responsibilities for this type of activity and that procedure NJMP 1.15 for conducting operational check flights was relevant to a high-speed taxi trial. Although the procedure was not comprehensive and has been significantly updated by the operator since the incident, it did provide some elements of risk mitigation which may have prompted the maintenance manager or the flight crew to delay the test until it had been properly planned and organised.

Having been presented with the taxi test requirement, the aircraft commander contacted the operator's maintenance control in order to establish the exact nature of the task and question if it fell within the OCF category, which would have required her to contact her fleet manager. The operator's duty maintenance manager instructed the commander to discuss the activity with the maintenance supervisor on-site, which devolved control of the activity to the aircraft commander and the maintenance supervisor, neither of whom had the necessary knowledge or experience of aircraft operational testing.

The lack of training and guidance for subcontracted maintenance organisations, and specifically the on-site maintenance supervisor and his team, regarding their roles and responsibilities in the preparation, briefing and conduct of taxi trials meant that the necessary engineering support was not provided to assist the crew to conduct the tests safely. This lack of training and guidance also meant the on-site maintenance team was unaware of the roles and responsibilities of the operator's maintenance and operations departments with regard to the trial. As such, they had no appreciation of the level of support they and the crew should have expected to receive.

These issues were identified in part by the operator's internal safety department investigation and a recommendation was made in their report to develop

Footnote

5 The wheel bay overheat warning is only relevant when the gear has been retracted after take-off. There is no brake overheat warning system available on the ground.

and implement specific additional procedures. The operator's response has been to amend the applicability of the OCF procedure NJMP 1.15 to include high risk ground test activities, such as high-speed taxi trials and engine ground runs. The amended procedure also adds definition to some elements of the role of the operator's maintenance manager when OCF activities take place. Whilst this is a positive improvement, further changes are recommended to fully address the maintenance issues highlighted. These should include separate and additional maintenance procedures for both internal and sub-contract maintenance participants to document the tasks, roles and responsibilities when requesting and participating in these high risk test activities and to highlight when procedure NJMP 1.15 should be referred to. The following Safety Recommendation is made:

Safety Recommendation 2010-064

It is recommended that NetJets Transportes Aéreos introduce maintenance procedures which document the tasks, roles and responsibilities of all maintenance personnel when requesting and participating in operational/functional check flights or flight crew operated ground tests.

Safety action

The operator carried out an in-depth internal safety department investigation into this incident. Their report included nine Safety Recommendations addressing the operational and engineering issues identified.