

ACCIDENT

Aircraft Type and Registration:	BAe 146-200, G-RAJJ	
No & Type of Engines:	4 ALF502R-5 turbojet engines	
Year of Manufacture:	1988 (serial number E2108)	
Date & Time (UTC):	23 February 2015 at 1854 hrs	
Location:	Guernsey Airport, Channel Islands	
Type of Flight:	Commercial Air Transport (Passenger)	
Persons on Board:	Crew - 4	Passengers - 47
Injuries:	Crew - None	Passengers - None
Nature of Damage:	Shock absorber damaged beyond economic repair, damage to left main landing gear and No 1 tyre burst	
Commander's Licence:	Airline Transport Pilot's Licence	
Commander's Age:	58	
Commander's Flying Experience:	8,428 Hours (of which 5,300 were on type) Last 90 days - 32 hours Last 28 days - 23 hours	
Information Source:	AAIB Field Investigation	

Synopsis

After the aircraft took off from Gatwick, the landing gear was selected UP but the gear position indicators remained red, indicating that the landing gear was not in the position selected. The crew followed the emergency checklist and selected gear DOWN and the indications changed to green, indicating that the landing gear was now down-and-locked. The crew elected to continue to Guernsey, Channel Islands and landed on Runway 27. On touchdown, the aircraft pulled to the left and the co-pilot reported that there was no brake pressure. The commander suspected a tyre had burst and that hydraulic pressure had been lost. He therefore changed to the alternative braking system, slowed the aircraft and vacated the runway. The flight crew continued to taxi the aircraft and eight minutes passed before Guernsey ATC were informed that a tyre may have burst. Another aircraft landed on the runway during this period and before a runway inspection was initiated.

Once G-RAJJ was parked, the crew discovered that the shock absorber on the left landing gear had separated and the tyre on the No 1 mainwheel had burst. Debris from the tyre and shock absorber was subsequently found on Runway 27. The shock absorber separated either as a result of a hard landing, or incorrect gas pressures and oil level in the shock absorber. The physical damage to the shock absorber diaphragm threads and locking bolts started at least two flight cycles prior to the accident flight and may have occurred whilst it was fitted to another aircraft.

History of the flight

The crew reported for duty at Birmingham Airport at 1430 hrs and flew the aircraft to Gatwick for a charter flight to Guernsey, Channel Islands. The aircraft took off from Gatwick at 1807 hrs; it was dark with good visibility and a light south-westerly breeze and scattered showers in the vicinity of the airport.

Once a positive rate of climb had been achieved, the commander who was pilot flying (PF), instructed the co-pilot to move the gear selector to UP. The landing gear was heard to travel and the nose gear indication showed green, but the position indicators for both main landing gear remained red, indicating that neither gear had locked in the UP position. The Standard Instrument Departure was followed and, at a safe altitude, the pilots referred to the emergency checklist for '*Gear Selector UP but Gear Does Not Lock Up*'. At 1811 hrs, ATC instructed the aircraft to climb to FL140. The crew's response was to request to remain at FL120 whilst they dealt with an "issue" with the landing gear. This was the first occasion ATC had been informed of a problem with the aircraft.

The crew actioned the emergency checklist and selected the landing gear DOWN. Shortly afterwards all three gear position indicators showed green, indicating that the landing gear was down-and-locked. The secondary landing gear indicators were checked and these also showed green. To assist with their decision making, the crew followed the DODAR¹ mnemonic. They established that there was sufficient fuel for the short sector with the gear down and, as there were no other abnormal indications, they decided they should continue to the passengers' expected destination. The co-pilot informed ATC that they had dealt with the situation and were proceeding to Guernsey with the landing gear in the DOWN position. The cabin crew were briefed and were subsequently informed that everything was normal and that they could carry on with the cabin service. On handover to Guernsey ATC the crew reported that they expected to make a normal approach and landing, although initially it might be flown at a slower speed than normal. A radar-vector approach was made to the ILS for Runway 27 and, prior to touchdown, ATC reported the wind as 260° at 21 kt. There were showers in the vicinity and the runway was damp, but there was no low cloud and visibility was greater than 10 km. The aircraft's landing mass was calculated to be 35,206 kg, which was 1,534 kg less than the maximum allowed.

All indications were normal during the approach but on touchdown the aircraft pulled to the left. The commander thought that a tyre on the left side had "blown", but there was no associated noise and he was able to keep the aircraft close to the runway centreline using the rudder. However, the brakes were ineffective and the co-pilot noticed that no pressure was indicated on the Green system gauge. He announced "NO BRAKE PRESSURE SWITCH TO ALTERNATE SYSTEM". The commander selected the alternative brake system² and the aircraft then responded "normally" to his braking inputs. He slowed the aircraft and vacated the runway without discussing the suspected tyre burst or brake pressure loss.

Footnote

¹ The mnemonic DODAR is used by the operator as an aid to decision making in abnormal circumstances. The D stands for Diagnose, O is for Options, the second D is for Decide, A is for Allocate and R is for Review.

² The normal brake system is the Green system and the alternate system is the Yellow system.

Once the aircraft was on the parallel taxiway, the crew noticed the aircraft was listing to the left. They agreed that it was likely that a tyre had burst and decided it was best to keep the aircraft rolling, so the co-pilot asked ATC, "WOULD YOU MIND GIVING US PROGRESSIVE TAXI, IT'S JUST THAT THERE'S A COUPLE OF ISSUES EMANATING FROM THE GEAR ISSUE, SO JUST KEEP AN EYE ON US AND IF WE COULD GET PROGRESSIVE THAT WOULD BE MUCH APPRECIATED."

One minute later the crew requested a remote parking stand in anticipation of having to investigate the landing gear problems. The aircraft had already passed the remote parking area, so the crew were told to continue along the parallel taxiway towards the Runway 27 threshold. ATC subsequently instructed them to re-enter Runway 27, after another aircraft had landed, and vacate again at the first intersection.

While they continued to taxi the aircraft, the crew noticed it was listing further to the left. The operator's chief engineer, who was there to provide overnight maintenance cover, occupied the flight deck jump seat. He suggested it was possible both tyres on the left side had burst but the commander discounted this. The commander believed an increased level of engine power would have been needed to taxi the aircraft if both tyres had burst. After discussing the matter, the crew decided to continue taxiing but to ask for a vehicle to attend to report on the condition. Consequently, eight minutes after landing, while taxiing along the runway, the crew asked ATC, "COULD YOU POSSIBLY GET SOMEBODY TO FOLLOW US, WE JUST WANTED TO GET A MONITORING... OUR LEFT UNDERCARRIAGE. IT LOOKS LIKE WE'VE LOST TWO TYRES ON TOP OF WHAT WE HAD." ATC asked if this meant that the aircraft had burst a tyre on landing and, when they were told this was the case, they delayed another aircraft's departure to allow the runway to be inspected.

After the aircraft vacated the runway again, ATC passed an observation from Airfield Operations that the aircraft was listing to the left. The Rescue and Fire Fighting Service (RFFS) followed the aircraft to its parking stand and it was subsequently discovered that the outer tyre on the No 1 mainwheel had burst and the left main landing gear shock absorber had separated into two parts.

No debris was found during the initial runway inspection but later a small piece of rubber was found on the parallel taxiway. The next morning, during the airfield's pre-opening inspection, a ring seal and more rubber was found close to the southern edge of Runway 27, approximately 100 m from the threshold. A subsequent inspection found a bolt head, attached to a piece of locking wire approximately 8 inches long, at the threshold.

Crew comments

The commander had previous experiences of unusual landing gear indications on the BAe 146, which he understood to have been caused by faulty microswitches. In this case the departure had felt smooth and he assumed that a faulty microswitch was likely to have caused the red indications when the gear was selected UP.

The commander did not stop G-RAJJ on the runway after landing in order not to block the runway or the taxiway. He considered it safe to taxi the aircraft with a burst tyre and with one failed hydraulic system, given that there were two other working hydraulic systems.

Runway contamination

As the aircraft taxied, another passenger aircraft landed without incident on Runway 27 before ATC was alerted to the possibility of a tyre-burst. The pilot of this aircraft only became aware after landing that the runway might have been contaminated and therefore filed an MOR.

Guernsey Airport's Senior Air Traffic Controller (SATCO) later observed that in previous tyre-burst or deflation occurrences, the aircraft involved halted immediately and notified ATC. This allowed the RFFS and Airport Operations to be alerted. The SATCO commented that if the crew had followed this procedure, the RFFS would have attended the scene and provided safety cover and assistance. Moreover, Airport Operations would have managed the recovery of any debris and informed ATC once the runway was available for the resumption of operations. In this instance, the damage only became apparent after the aircraft had parked and it was realised there was a risk that debris might have contaminated the manoeuvring area.

Operator's investigation

An internal investigation by the operator determined that a PAN call should have been made by the flight crew to alert ATC at Gatwick to the landing gear malfunction. Also, as the crew did not know the cause of the abnormal gear indications, a more suitable decision was to return to Gatwick (which has a longer runway) than to continue to Guernsey with the landing gear in the DOWN position.

Following a suspected tyre-burst or other landing gear malfunction on landing, the operator expects an aircraft to be stopped on the runway, or in certain circumstances to stop once clear of the runway, and alert ATC without delay. An external inspection should be sought and, if this indicated that a tyre had burst, the aircraft should not continue to taxi as this can increase the load on the other tyres.

Recorded information

The aircraft was equipped with a flight data recorder (FDR) and cockpit voice recorder (CVR), both of which used a tape recording medium, and a solid-state quick access recorder (QAR) which received the same input data stream as the FDR. The CVR was not downloaded as the recording of the accident flight would have been overwritten. The FDR was downloaded at the AAIB and a copy of the QAR data for the accident flight was provided to the AAIB by the operator.

Due to the age of the aircraft and the relevant regulations at the time of manufacture, parameters recorded by the FDR (and QAR) such as Weight on Wheels, gear lever selection and brake pressures, that would have been useful for this investigation, were not recorded. However, the landing gear (all down-and-locked) and landing gear (all up-and-locked) discrettes (sampled every second) were captured.

A time history of the salient parameters from the QAR for the takeoff from Gatwick Airport is shown at Figure 1. The data shows that during the climb, at between 75 ft and 99 ft agl, the landing gear was no longer down-and-locked, which was consistent with the gear selector

being moved to the UP position. However, the landing gear did not go into the up-and-locked position, which was consistent with the position indicators showing red. The gear returned to the down-and-locked position just over eight minutes later, when the aircraft was at about FL120, which was consistent with the gear selector being moved to the DN position and the position indicators showing green. The landing gear remained in this state for the rest of the flight.

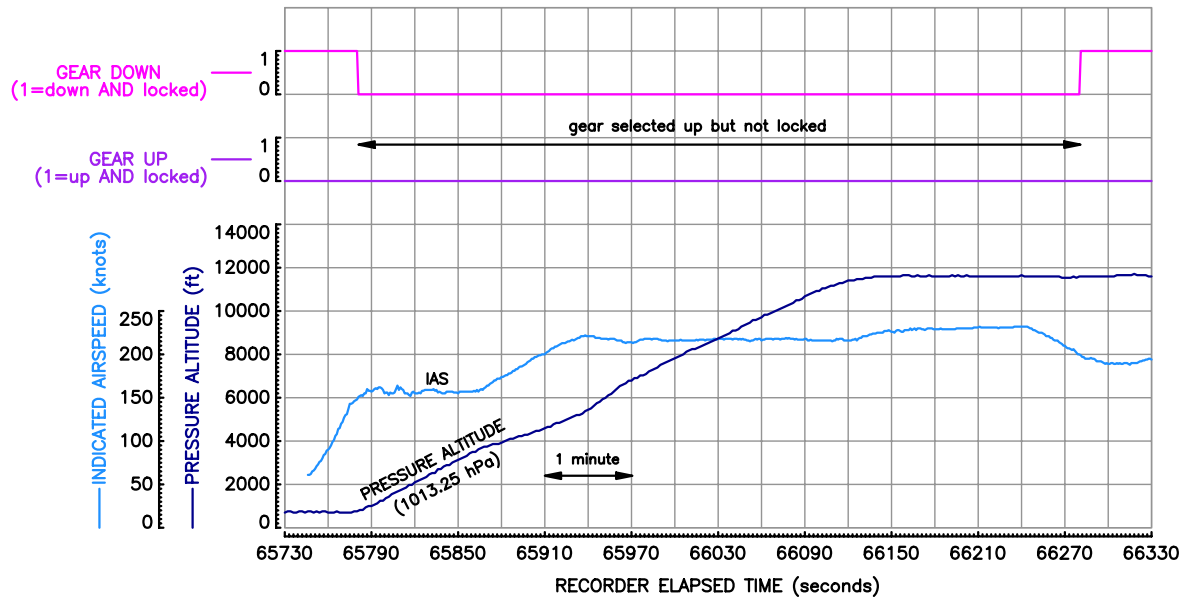


Figure 1

G-RAJJ salient flight data from QAR

FDR data quality

From the downloaded data it was evident that there was a fault with the FDR in that several of the tape tracks, including the track containing the accident flight, contained a significant amount of corrupted data, while the remaining tracks were good. When the operator was asked to provide evidence to show that the FDR was being checked annually for correct operation, in accordance with the regulations³, it was evident that the QAR data recordings were being used to demonstrate this instead, and that the last overhaul of the FDR had been conducted 25 months previously, in January 2013. A functional check of the FDR had been made in July 2014; however, this did not involve checking the quality or consistency of the data and so did not flag up any faults.

This oversight by the operator has since been rectified and the correct acceptable means of compliance to the requirements of the regulations is now being followed.

Footnote

³ Commission Regulation (EU) No 965/2012 CAT.GEN.MPA.195 Preservation, production and use of flight recorder recordings, requires that "(b) The operator shall conduct operational checks and evaluations of flight data recorder (FDR) recordings, cockpit voice recorder (CVR) recordings and data link recordings to ensure the continued serviceability of the recordings". The acceptable means of compliance, given in EASA document Acceptable Means of Compliance (AMC) and Guidance Material (GM) to Part-CAT (April 2014), requires that this should be done annually for tape-based flight recorders.

Systems description

The main landing gear is a twin-wheel, inward retracting, lever suspension incorporating a nitrogen-charged two-stage shock absorber. Hydraulic pipes for the braking system are mounted on the outside of the landing gear. A side stay is installed between the main landing gear and the airframe to provide a mechanically-locked support when the gear is in the extended position. During the retraction sequence, movement of the direction link causes the shock absorber and the wheel lever to fold, which shortens the landing gear to allow it to fit into the wheel bay. The shock absorber remains fully extended during the retraction sequence, Figure 2.

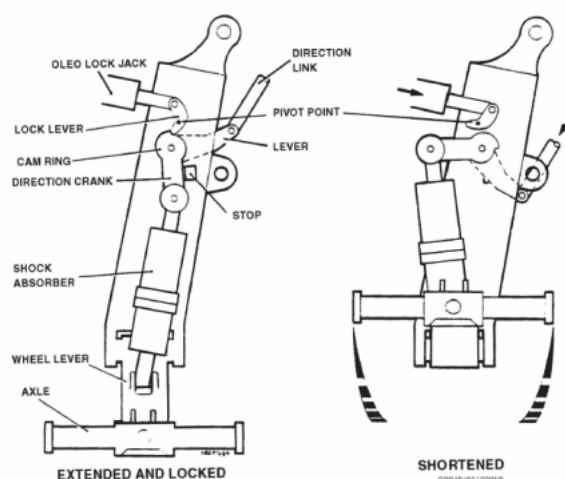


Figure 2

Schematic of main landing gear

The shock absorber assembly consists of three main parts: an outer cylinder, inner cylinder and a piston rod, Figure 3. The stationary outer cylinder is connected at an 'eye end' to the main landing gear assembly by a crank lever and the inner cylinder is connected at an eye end to the wheel lever. The piston rod is bolted to the outer cylinder and the inner cylinder is free to slide within the outer cylinder.

The inner cylinder houses the 1st stage floating piston, which separates the oil from the low pressure nitrogen charge. The cylinder is supported at its upper end by a diaphragm, which incorporates a recoil ring. The recoil ring is free to float between the drilled and slotted flanges of the diaphragm, permitting free or restricted flow of oil, according to its position (one of these slotted flanges had broken during the event). The diaphragm is screwed into the inner cylinder and is torque-loaded and locked in place by two wire-locked bolts.

A 2nd stage floating piston is installed inside the piston rod to separate the oil from the high pressure nitrogen charge. A piston head containing a valve plate is screwed into the lower end of the piston rod and is secured by four locking bolts. The valve plate is free to float between the valve housing and the drilled face of the piston head to permit free or restricted flow of oil between the cylinders and the piston rod, according to the position of the valve plate. A central orifice in the valve plate allows a metered flow of oil across the valve plate.

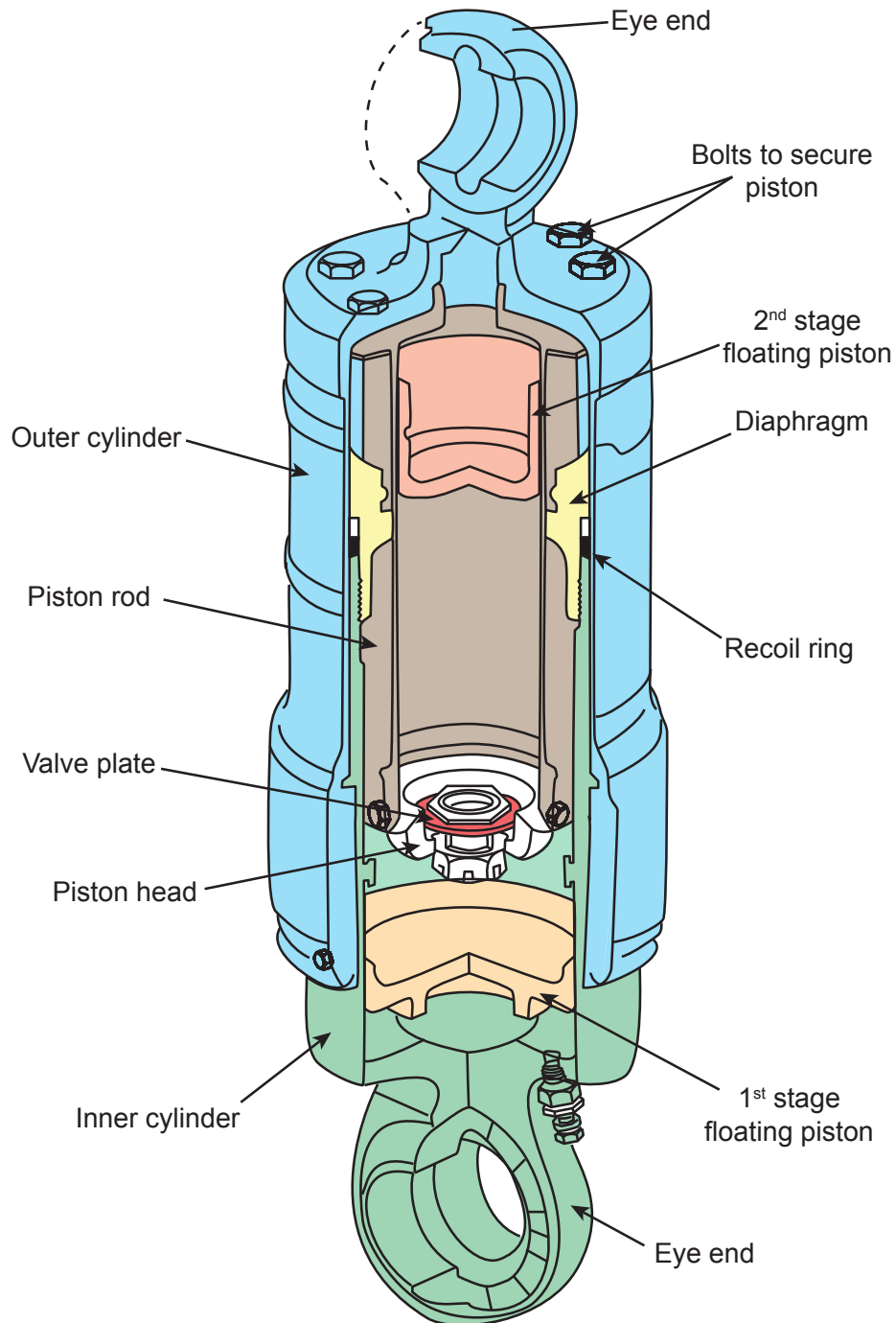


Figure 3

Cutaway of shock absorber assembly

Operation of the shock absorber

When a load is applied to the shock absorber the inner cylinder telescopes into the outer cylinder and displaces the oil above the diaphragm. The oil forced through the orifices in the diaphragm generates pressure against the 1st stage floating piston in the inner cylinder to compress the nitrogen further. The recoil ring is forced against the slotted lower flange of the diaphragm allowing oil to pass freely into the increasing volume around the inner cylinder.

If the load causes more than approximately 50% closure of the shock absorber, the nitrogen pressure above the 2nd stage floating piston in the piston rod equals the nitrogen pressure below the 1st stage floating piston in the inner cylinder. On further closure, oil displaced from the inner cylinder opens the valve plate and flows without restriction to act on the floating piston in the piston rod, causing further compression of the nitrogen. Shock loads are absorbed by the dual action of forcing oil through the orifices and the increase in nitrogen pressures.

When the recoil action takes place, the shock absorber extends to its full length and the diaphragm makes contact with its mechanical stop. During recoil, nitrogen pressure above the floating piston in the piston rod forces the floating piston downwards and displaces oil into the inner cylinder. This action causes the plate valve to seat on the piston head. Oil can now only transfer through the central orifice in the valve housing and this restriction of flow provides a damping action. As the shock absorber extends, the nitrogen pressure above the 2nd stage floating piston in the piston rod drops below the pressure in the space above the 1st stage floating piston in the inner cylinder. This allows the 1st stage floating piston in the inner cylinder to move upwards and displace oil through the diaphragm. Oil displaced from the decreasing volume around the inner cylinder forces the recoil ring up against the drilled upper flange of the diaphragm causing a restriction to flow, further damping the recoil.

Landing gear indication

The primary landing gear position indication is provided by an array of six annunciators: three red and three green. The annunciators are controlled through the proximity switches and indicate the following:

Green annunciator illuminated:	Gear down-and-locked
Red annunciator illuminated:	Gear not in position selected
Neither annunciator illuminated:	Gear up-and-locked

A visual indication that the landing gear is not in the selected position is provided by a red warning light on the landing gear selector lever (Figure 4). In addition, standby indicators are located beneath the landing gear emergency selection handle. These indicators only provide an indication when the gear is down-and-locked.

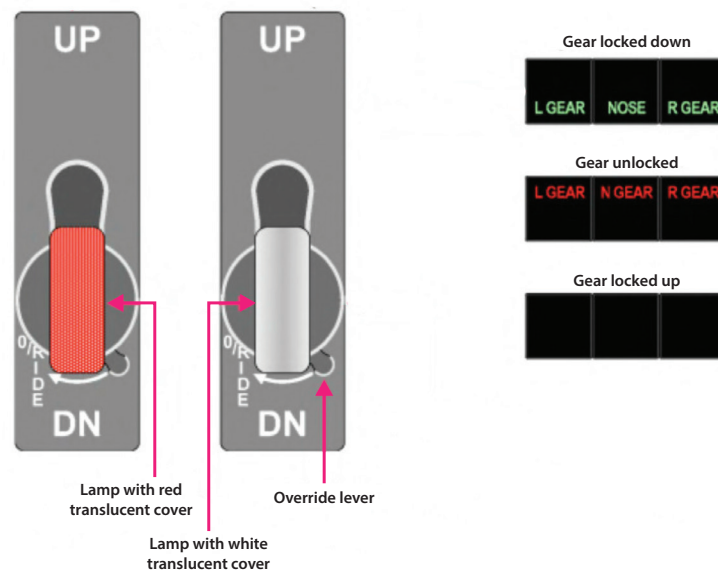


Figure 4
Landing gear annunciators

Wheel braking system

The aircraft is fitted with four mainwheels numbered 1 to 4 from left to right. The mainwheel braking system uses the Green and Yellow hydraulic systems with the Green system used for normal braking⁴ and the Yellow system as standby, Figure 5. A selector switch, located on the centre console, allows the crew to select the hydraulic system used for braking. The braking system incorporates hydraulic fuses, anti-skid control valves, a control box and a brake pack fitted to each mainwheel. Two hydraulic pressure gauges, one each for the Green and Yellow system, are mounted on the instrument panel and provide an indication of the hydraulic pressure applied by each of the four Brake Control Valves, which are mechanically linked to the pilot's corresponding pedal. The pressure transducers for these pressure indicators are mounted upstream of the anti-skid valves, which control the pressure from the hydraulic supply to the brake packs.

The anti-skid control box receives signals from rotary Weight on Wheels (WoW) switches and wheel speed transducers fitted to each mainwheel. When the logic determines that the aircraft is airborne, the control box sends a signal to the anti-skid control valves, dissipating the hydraulic pressure in the brake lines. On landing, full anti-skid functionality is obtained when either the outboard or inboard WoW on each axle is active, or at least one wheel on each main landing gear leg has spun up.

Each brake pack is provided with a dedicated Green and Yellow hydraulic hose. The Green and Yellow system hoses are separated and are positioned on either side of the landing gear leg. Each hydraulic brake pipe is equipped with a hydraulic fuse located in the forward

Footnote

⁴ Most BA146 aircraft use the Yellow system as the primary system; however G-RAJJ, which was pre-mod HCM00967A, uses the Green hydraulic system as the primary.

landing gear bay pressure bulkhead. The hydraulic fuses monitor the pressure downstream and if they detect a drop in pressure they close, preventing the loss of hydraulic fluid from the hydraulic system. Hydraulic fuses can only be reset on the ground. In the case of a single hose failure, the hydraulic fuse only isolates the affected brake pack and brake pressure would still be provided to the other three brake packs. Switching to the alternative hydraulic system would restore braking to all four mainwheels.

On aircraft 157

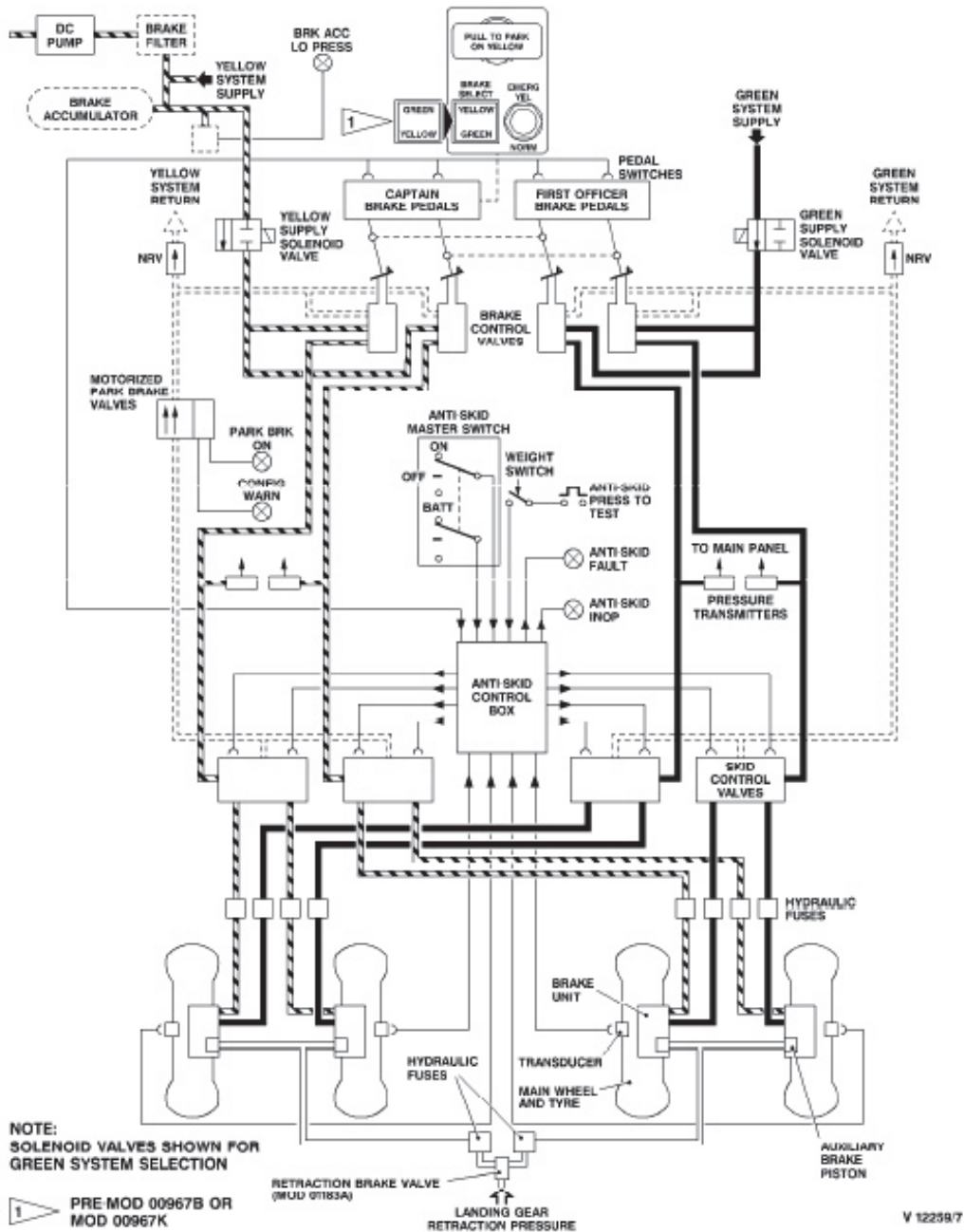


Figure 5
Aircraft hydraulic system

Damage to aircraft

Following the accident the shock absorber inner cylinder was found to have separated from the outer cylinder, Figure 6. The top surface of the wheel lever had sustained damage as a result of contact with the outer cylinder. The inner cylinder had made contact with the No 1 brake pack Green hydraulic system quick release pipe, causing it to detach from its connecting union. The operator's engineers later established that the Green hydraulic system had only lost one litre of fluid.

The inner cylinder also rubbed against the inner sidewall of the outer tyre (No 1 mainwheel), which had punctured and deflated. The frame, which runs down the centre of the lower fuselage between the main landing gear bays, had been damaged. Tyre marks indicate that the No 2 mainwheel caused this damage during the retraction sequence. The sheared bolt head attached to a long section of locking wire recovered from the runway was identified as being from one of the shock absorber diaphragm locking bolts. There was no damage to the bottom of the wheel lever.

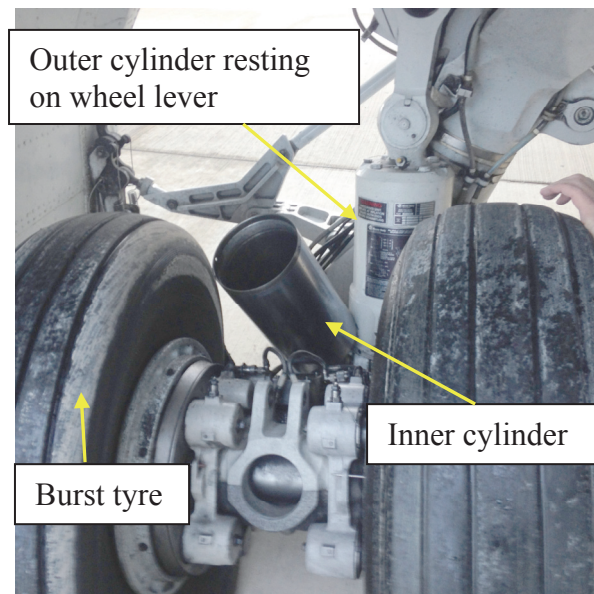


Figure 6
Left main landing gear

Examination of the shock absorber

Initial examination

After the aircraft landed at Guernsey, the operator's engineers refitted the inner cylinder on the shock absorber into the outer cylinder in order to move the aircraft into the hangar. This action damaged the threads on the diaphragm, which subsequently increased the difficulty in establishing the reason why the shock absorber separated. However, prior to reassembling the shock absorber, the engineers carried out a visual inspection of the threads on the inner cylinder, where the diaphragm is located, and reported that they were clean and free from any visible signs of corrosion, contamination or any significant wear.

Detailed examination

The component manufacturer, under the supervision of the AAIB, carried out a detailed examination of the shock absorber. This examination required parts of the shock absorber to be sectioned and established the following:

- There was some damage to the eye-ends on both the inner and outer cylinder caused by contact with the main landing gear.
- The surface finish on part of the outer cylinder had abraded away as a result of having been in contact with the rotating tyre.
- The 1st stage floating piston was missing. This piston would have been forced out of the shock absorber by the pressurised nitrogen when the inner cylinder came out of the outer cylinder during separation.
- The threads on the inner cylinder (steel) were found to be intact, whereas the threads on the diaphragm (aluminium alloy) had sheared in a direction consistent with a compressive load forcing the diaphragm and inner cylinder together.
- Examination of the sheared thread shards from the diaphragm suggested that the threads were intact prior to shearing. This indicates that the threads sheared during one event.
- The location of the diaphragm thread shards within the shock absorber suggested that the shards were present whilst oil was still flowing in the shock absorber. This indicates that thread shearing occurred before separation of the shock absorber.
- The heads of the two diaphragm locking bolts had sheared. The head of one bolt was recovered from the runway at Guernsey. The other bolt head was not recovered.
- The locking bolt fracture surfaces only showed evidence of fracture due to shear overload. These bolts had failed in a direction consistent with a tensile load forcing the diaphragm and inner cylinder to separate.
- One of the slotted flanges had broken away from the diaphragm. It was concluded from the damage to the flange that the sheared diaphragm locking bolt head had become trapped between the flange and the outer cylinder bore causing the flange to break, Figure 7.
- Mechanical damage on the diaphragm, shim, recoil ring and outer cylinder, was assessed as having been caused by the bolt head, which suggests that the locking bolts had sheared some cycles before separation of the shock absorber.

- One small area of fatigue cracking was seen in the threads on the diaphragm, in the first full thread immediately below one of the locking bolt holes. The cracking consisted of two fatigue cracks, one on each side of the thread. This damage was consistent with the threads on the diaphragm and inner cylinder having been cyclically loaded in both tension and compression.
- The hardness of the diaphragm and inner cylinder materials were within specification. The locking bolt hardness was slightly above specification, but this is not thought to have contributed to its fracture, or separation of the shock absorber.
- The material microstructures of the diaphragm and inner cylinder were normal.

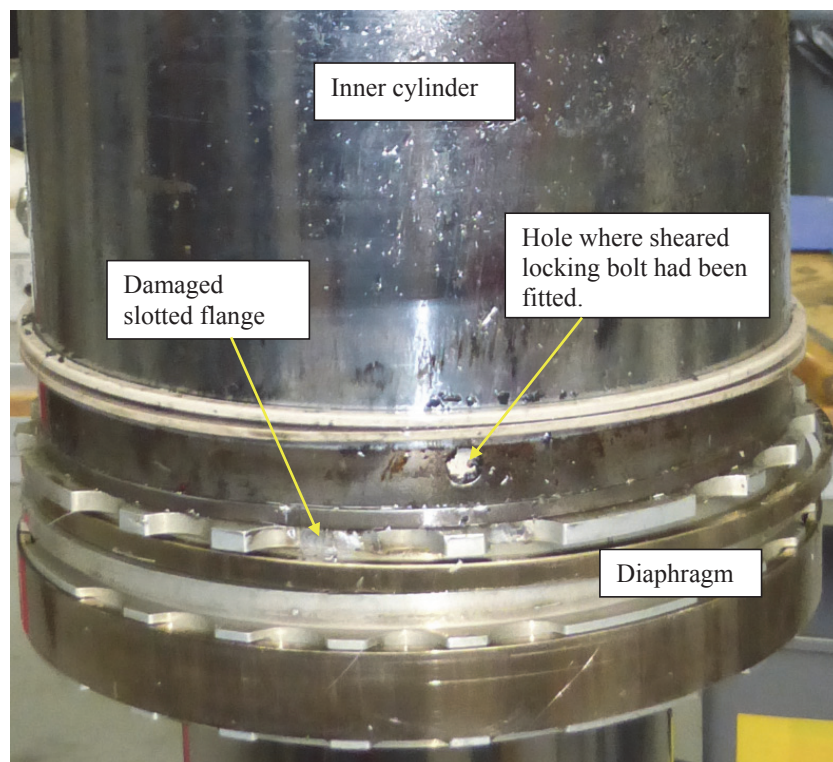


Figure 7
Inner cylinder and diaphragm

Maintenance

The operator reported that the last maintenance on the shock absorber had been carried out during the 'C' check when the shock absorber was replaced and the oil level, nitrogen pressures and landing gear extension would have been checked. There had been no reports during the subsequent daily inspections of the extension of the left landing gear leg appearing to be incorrect. There were also no records of any reports of a hard landing having occurred prior to the accident flight.

History of the shock absorber

The shocker absorber fitted to the left landing gear on G-RAJJ (serial number DRG/5455/87) had a life limit of 60,000 cycles and an overhaul interval of 15,000 cycles or 12 years. It had last been overhauled in June 2003 and then fitted to an Avro RJ-70 and operated until February 2010 when the aircraft was put into storage.

In April 2013 it was removed, in a serviceable condition, from the Avro RJ-70 and visually inspected before being placed in storage. The Cycles Since New (CSN) was recorded as 33,394 and the Cycles Since Overhaul (CSO) as 3,882. An EASA Form 1 for the component was issued on 9 July 2013 (Release number M5754). The shock absorber was subsequently provided to the operator on 5 January 2015.

The shock absorber was fitted to G-RAJJ during the 'C' check, which was completed on 8 January 2015 and flew a further 27 cycles, prior to the accident flight on 23 February 2015. The next overhaul was due on 9 June 2015.

Both the aircraft and component manufacturer reported that they were unaware of any previous occurrences of a separation having occurred on this type of shock absorber.

Analysis

Overview

The investigation concluded that the physical damage to the shock absorber diaphragm threads and locking bolts started at least two flight cycles prior to the accident flight and may have occurred whilst it was fitted to another aircraft. The final failure of the thread on the diaphragm in the shock absorber would have occurred during the landing at Gatwick, but separation did not occur until the next take-off when the recoil forces forced the shock absorber apart.

Separation of the shock absorber

The loss of the 1st stage floating piston and damage to the threads on the diaphragm, caused when it was reassembled, made it difficult to establish why the shock absorber separated. The component manufacturer reported that they had never previously experienced a BAe 146 shock absorber separating, nor were they aware of other occasions when the diaphragm locking bolts had sheared or fatigue damage had been found on the threads on the diaphragm.

The number of score marks on the bore of the outer cylinder indicated that the head of the locking bolts had sheared off at least two flight cycles before the shock absorber came apart. Shards from the sheared thread on the diaphragm were found throughout the shock absorber indicating that the oil had moved them as the shock absorber cycled.

From the physical damage it was assessed by the component manufacturer that the initiating factor was most likely to have been the threads on the diaphragm jumping across the threads on the inner cylinder. This jumping movement of the threads would have applied a shear load on the diaphragm locking bolts causing them to fracture. Thread jumping could

have occurred one thread pitch at a time, or several at a time, thereby reducing the number of threads in engagement. During the subsequent landing at Gatwick, the compression damping load on the diaphragm exceeded the shear fracture load of the reduced number of engaged threads causing them to shear and thereafter shearing the non-engaged threads. As the aircraft departed Gatwick the shock absorber would have extended during recoil; however, because the threads on the diaphragm had sheared, there was no longer a mechanical stop to prevent the shock absorber from separating.

At some time prior to the fracture of the locking bolts, the torque between the diaphragm and the inner cylinder would have reduced, allowing fatigue cracks to develop on the first full thread on the diaphragm. These fatigue cracks did not cause, or contribute, to the separation of the shock absorber.

As a consequence of the separation, during the retraction sequence the left main landing gear would not be able to 'shorten' and fit into the bay, which resulted in the No 2 mainwheel fouling on the frame. It is likely that the right main landing gear, No 3 mainwheel, then fouled on the No 2 mainwheel preventing it from fully retracting. This resulted in the illumination of both main landing gear position red indicators.

Examination of the shock absorber indicated that it had been correctly manufactured and assembled. Therefore, for the threads on the diaphragm to jump, and the locking bolts to shear, the shock absorber must have experienced recoil loads beyond its design load. This load could have resulted from a hard landing, with a subsequent bounce, or incorrect gas pressures and oil level in the shock absorber. The aircraft operator reported that the shock absorber had not had any maintenance since it had been fitted to the aircraft and there had been no reports of it having experienced a heavy landing. The shock absorber had not been disassembled since its last overhaul in 2003 and the physical damage to the diaphragm thread and locking bolts may have occurred whilst it was fitted to another aircraft.

Loss of Green hydraulic pressure

The co-pilot reported that shortly after touchdown he noticed that there was no brake pressure reading on the Green system brake indicator. However, the investigation could not establish why this should be the case.

For there to have been no brake pressure, there must have been either no hydraulic fluid or pressure available. However, neither pilot noticed any hydraulic warnings and the engineers reported that the Green system had only lost one litre of hydraulic fluid. This indicates that the hydraulic fuse in the Green No 1 brake supply line operated after the union became disconnected.

The brake pressure transducers, which supply the brake pressure gauges, are upstream of the anti-skid control valves and operation of the anti-skid system has no effect on the brake pressure displayed to the pilots. Therefore the anti-skid valve could not have caused the loss of pressure. Moreover, the anti-skid control box does not differentiate between the Green or Yellow system with regards to anti-skid and, therefore, any anti-skid signal would be the same regardless of which hydraulic system the pilot had selected.

A brake pressure check is carried out during the landing checklist. On the accident flight the crew did not detect a loss of brake pressure during this check. Switching between the hydraulic systems is performed by solenoid valves in the Green and Yellow systems. Since the accident there has been no indication of a fault with the solenoid valves and therefore it is unlikely that a solenoid valve failed.

The disconnection of the Green hydraulic hose to the brake pack would only have affected the braking on the No 1 mainwheel and would not have affected the braking efficiency of the other wheel on the axle. Therefore the pilot should have been able to stop the aircraft in a controlled manner using the Green hydraulic system.

Crew response

The pilots followed the emergency checklist correctly and resolved the abnormal landing gear indication, but they did not appear to have considered the possibility that this indication was caused by a mechanical malfunction. This was because the takeoff run felt smooth and the commander's thinking was influenced by his previous experience of abnormal gear indications.

There was a delay before ATC was informed of a problem but no PAN call was made and no details were shared other than there was an "issue" with the gear. The crew believed they properly assessed the situation before deciding to continue to their passengers' destination; it was a short sector, the only abnormal indication was that they were cruising with the gear down and there was plenty of fuel to cope with the extra drag. The operator's assessment was that a more suitable decision would have been to return to Gatwick.

The landing roll was well-controlled by the crew in response to a burst tyre and the failure of one brake system. However, the operator and ATC expect an aircraft with a suspected burst tyre to be brought to a halt and not to continue taxiing until an external check has been completed. In this case the aircraft was not stopped and a protracted taxi routing was followed, even though the crew suspected a burst tyre and knew the Green brake system had failed and the aircraft was listing to the left. Their decision-making was influenced by not wanting to block the runway or taxiway and to continue to a parking stand.

Communication with ATC

Airport air traffic controllers expect prompt communication from aircraft when the crew are alerted to a circumstance that could cause contamination of the manoeuvring area. This allows an immediate inspection to be carried out before other aircraft are placed at risk.

In this instance, Guernsey ATC were not informed by the crew about the possibility of a tyre-burst on landing until the aircraft had taxied and some eight minutes had elapsed. Consequently ATC were unaware that the runway was contaminated and allowed another aircraft to land.