No. 17

British Eagle International Airlines Ltd., Bristol Britannia 308, G-ANCG, accident at Manston Aerodrome, Kent, United Kingdom, on 20 April 1967. Accident report No. EW/E/04, undated, released by the Board of Trade, United Kingdom, C.A.P. 301

1. - Investigation

1.1 History of the flight

The aircraft had returned to the servicing base at London Airport from a training flight at about 0400 hours on 19 April with two recorded defects; these were a faulty propeller and a leaking retraction sequence valve in the port undercarriage. The night shift remedied the propeller defect and changed the leaking sequence valve. The following night the same ground crew adjusted the replacement sequence valve and carried out an undercarriage retraction test. They were satisfied that the undercarriage was in order and recorded the work they had done in the technical log. The aircraft was released for service at about 0200 hours on 20 April.

At 1001 hours the aircraft, carrying passengers and cargo for Adelaide, took off from London (Heathrow) Airport with a first stop at Kuwait. After take-off, the port undercarriage failed to retract and a few moments later the pilots observed that the 'not locked' warning light was on. Air traffic control told them that the port undercarriage had not retracted. The crew selected the undercarriage 'down', checked that it locked down correctly and that all the pressures and contents gauges for the hydraulic system were normal and selected 'up' again. The 'not locked' warning light for the port undercarriage remained on. This sequence of selections was carried out again with the same result.

The Commander then sent a crew member aft to check the position of the port undercarriage: he reported that the undercarriage doors were not quite closed. The crew re-selected 'down', noted that the warning lights showed 'locked down' and re-selected 'up'; the 'not locked' warning light remained on. The Commander thereupon abandoned the flight and fuel was jettisoned in preparation for a landing at London (Heathrow).

When the undercarriage was next selected 'down' for landing the undercarriage warning lights indicated that none of the legs was locked down, and the hydraulic pressure and contents gauges now registered zero. The crew operated the emergency selector, but the warning lights still indicated 'not locked down'. The approach to land was therefore discontinued and the aircraft held at Epsom. The hydraulic system hand pump was used to try to lock the undercarriage down, but without success, and the Commander then called by radio for technical advice from his Company.

Under instruction from the Company's engineers on the ground, who had sought advice from the aircraft manufacturer, and with the help of the two supernumerary engineers on board the aircraft, attempts were made to lock the undercarriage down using various combinations of the hydraulic system controls. The hydraulic lines were broken into and the system replenished with water and other fluids available on the aircraft. However, the warning lights continued to show 'not locked down' and observers on the ground confirmed that the starboard main undercarriage was unlocked.

The Commander decided to make an emergency landing at Manston where, at his request, a foam carpet was laid on the runway. Following a 'dummy' approach a landing approach was made, the two inboard engines being feathered at 400 ft to minimize the risk of pieces of propeller blade becoming detached and entering the aircraft cabin. The aircraft touched down about 1 200 ft after the beginning of the foam carpet. Almost immediately the starboard main undercarriage collapsed and the starboard outer propeller hit the ground. The aircraft began to swing to starboard, leaving the foam carpet about 900 ft further on, and continued to swing across the runway, running on the port main undercarriage, the nose undercarriage and the starboard wing. It crossed the taxiway along the northern side of the runway almost at right angles to the direction of touchdown, and as it passed over the drainage gulleys the port and nose undercarriage collapsed rearwards. The jolt operated the crash inertia switches causing the aircraft's fire bottles to discharge. The aircraft slid on its belly on the grass for a further 250 ft before coming to rest. The occupants immediately began an emergency disembarkation which was completed in less than a minute.

Fire and rescue appliances, which had been stationed in readiness on the south side of the runway, had followed the aircraft as it ran along the ground. The passengers, who were already leaving the cabin when the appliances arrived, were given full assistance, and full fire precautions were taken.

1.2 Injuries to persons

Injuries	Crew	Passengers	Others
Fatal			
Non-fatal			
None	11	54	

1.3 Damage to aircraft

The aircraft was substantially damaged but repairable.

1.4 Other damage

Seven runway lights on the crash strip were destroyed.

1.5 Crew information

Flight crew

Captain D. Chubb, aged 32, obtained a private pilot's licence in 1952, and was commissioned in the Royal Air Force in the same year. He obtained a commercial pilot's licence in 1956, with an instrument rating, and joined Cunard Eagle (now British Eagle International Airlines) in January 1957. In 1962 he converted his commercial pilot's licence to an airline transport pilot's licence; this licence was endorsed for Britannia aircraft in Group 1 and was valid at the time of the accident. He was promoted to Captain on Britannia aircraft in June 1965, and had completed the mandatory checks at the appropriate intervals. His last flight before that on which the accident occurred was on 14 April 1967, and in the previous 90 days he had completed approximately 230 hours flying, of which 56 hours 32 minutes were in the last 28 days. Captain Chubb's total flying time was 7 254 hours, of which 1 874 were in Britannia aircraft and 1 295 in command of Britannias.

First Officer R. Hughes, aged 37, qualified as a pilot in the Royal Air Force; he obtained a senior commercial pilot's licence in 1957 which was converted to an airline transport pilot's licence in 1959. This licence was endorsed for Britannia aircraft and was valid at the time of the accident. He joined British Eagle International Airlines in April 1960, and was promoted to First Officer on Britannias in May the following year; all his mandatory checks had been completed at the appropriate intervals. His total flying time amounted to approximately 7 000 hours, of which 3 840 were in Britannia aircraft. He had accumulated 170 hours flying in the 90 days prior to the accident, of which 45 hours were in the last 28 days.

First Officer G. Farley, aged 45, qualified as a pilot in the Royal Air Force in 1941. He took out a private pilot's licence in 1946, and obtained an instructor's certificate in 1948. He obtained a commercial pilot's licence in January 1965, and qualified for an instrument rating in December the same year. This licence was endorsed for Britannia aircraft and was valid at the time of the accident. Mr. Farley joined British Eagle International Airlines in December 1966, and had completed his mandatory checks at the appropriate intervals. He had accumulated a total of 4 467 hours, of which 77 had been flown in the 90 days prior to the accident and 30 in the 28 days before the accident.

Navigating Officer D. Sherriff, aged 33, served as a navigator in the Royal Air Force and obtained a flight navigator's licence in September 1966; it was valid at the time of the accident. He joined British Eagle International Airlines in June 1966, and at the time of the accident had accumulated a total of 4 628 hours flying, of which 708 were in Britannia aircraft. In the 90 days prior to the accident he had flown approximately 252 hours, of which 50 were in the last 28 days.

Flight Engineer P. James, aged 35, had been a Chief Technician in the Royal Air Force. He joined British Eagle International Airlines in November 1966, and took up his duties as a Britannia flight engineer in April 1967. At the time of the accident, Mr. James held a valid flight engineer's licence endorsed for Britannia aircraft; he had 320 hours flying experience as a flight engineer including 275 hours in Britannia aircraft. He had flown approximately 240 hours in the 90 days prior to the accident, of which 67 hours were in the last 28 days.

Cabin crew

All the cabin staff had completed the operator's check at the appropriate intervals.

Supernumerary crew

Mr. A. Daly and Mr. B. Morgan were to perform ground duties at stops en route to Adelaide.

1.6 Aircraft information

G-ANCG was built at Belfast in 1959 and exported to Argentina. It was purchased by British Eagle International Airlines in April 1964, by which time it had completed 4 348 hours flying. In November 1964, ownership was transferred to British Eagle (Liverpool) Ltd. A United Kingdom certificate of airworthiness was reissued in November 1964, and was valid at the time of the accident, when the aircraft had completed 10 682 hours flying.

At the time of take-off, the aircraft weight and centre of gravity were within the authorized limits. Before landing, fuel was dumped to reduce the weight below the authorized maximum for landing.

1.7 Meteorological information

The surface wind at Manston was westerly at 10-15 kt. Otherwise the weather was of no significance in this accident.

1.8 Aids to navigation

Of no relevance in this investigation.

1.9 Communications

Satisfactory VHF/RT communication was maintained throughout the flight.

1.10 Aerodrome and ground facilities

Manston is a Royal Air Force aerodrome which is available, among other things, for civil aircraft on diversion. Its concrete runway 9 000 ft long and 200 ft wide is aligned 110°/290°. There are standing arrangements under which a fire extinguisher foam carpet may on request be laid for an aircraft making an emergency landing. Following a request from Captain Chubb, laying of a foam carpet was commenced at 1452 hours and completed at 1505 hours. The carpet was 3 900 ft by 90 ft and was laid along the centre line of the runway from the touchdown point, approximately 1 000 ft from the 290° threshold. Crash, fire and associated back-up facilities were arranged by the Royal Air Force and fire and rescue appliances were stationed on the south side of the strip so that they could follow the aircraft along the runway.

1.11 Flight recorders

No information was contained in the report.

1.12 Wreckage

Inspection at the scene of the accident showed that the aircraft had touched down about 3 000 ft past the threshold of the runway, half-way along the prepared foam carpet. The starboard undercarriage had collapsed immediately and the starboard wing tip had touched the ground. In consequence, the aircraft had swung to starboard out of the foam carpet 900 ft further on. It came to rest on the grass about 75 ft from the runway with all three undercarriages folded up.

When the aircraft was raised, inspection revealed that the hydraulic shuttle valve at the head of the port main retraction jack had been parted from the jack by the fracture of its main attachment bolt. Witness marks on both components showed that this was the result of the rear jacking point on the rear axle striking the banjo union several times, indicating that the retraction sequence valve had been functioning incorrectly.

Following inspection at the site where no other damage, except that caused by the emergency landing, was found the aircraft was moved to a hard standing where it was supported on jacks in readiness for systems tests.

1.13 Fire

There was no fire. Foam was applied immediately as a precaution against the ignition of spilt fuel, CO_2 was used in the engine nacelles, and the starboard outer engine, which overheated, was cooled by applying water. The aircraft fire bottles had operated automatically.

1.14 Survival aspects

The cabin crew had some three hours' warning of the impending emergency landing. They were able to carry out the preparatory drills for the emergency with great thoroughness. The passengers were well briefed on the appropriate measures to be taken against the decelerations during the landing and on the drills for the emergency disembarkation; to assist in this, suitable individuals were seated adjacent to the emergency exits. The operating crew were able to consider and prepare for the possible consequences of the unsafe undercarriage and the landing was well executed.

The occupants of the aircraft completed the emergency disembarkation in 55 seconds although the main entry door was stuck and could not be opened. It was later found that a stronger pull than that given at the time would have opened it. The rapidity of the disembarkation and the speedy arrival of the fire and rescue appliances, as revealed by the photographic record of the incident, resulted in the disembarking passengers running into and across the path of the approaching appliances. There was a consequent risk of someone being run down and this needs to be borne in mind in the event of any future similar incident in darkness or fog.

1.15 Tests and research

Tests were made at Manston of the operation of the port undercarriage, and the undercarriage retraction sequence valve settings were investigated. Information on the operation of the sequence valve and its adjustment is given in Appendix 1 to this report and a diagram of the Britannia landing gear in Appendix 2.

With the aircraft jacked up an attempt was made to operate the undercarriage with the hydraulic hand pump, the system having been reconnected and replenished. The undercarriage would not operate when selected 'up' until the system pressure had been increased to normal operating pressure (4 000 psi) and the selector exercised. This was probably due to contamination of the selector by the fluids used in the emergency in the air. When the undercarriage started to retract, it did so without the bogie having rotated.

With the radius rod ground locking pin fitted, the port bogie was rotated to its locked position (i.e. 'tiptoe'), using the hand pump. The sequence valve overtravel dimension (i.e. the clearance between the travel limiting nut and the adjacent face of the valve housing) was then checked and found to be 0.215 in; the correct dimension is 0.160 in minimum to 0.170 in maximum. The test was repeated using the electrically driven main hydraulic pump and an initial pressure of 4 000 psi. With the bogie rotated to 'tiptoe' and locked, the sequence valve overtravel was found to be 0.188 in. A further test resulted in a measurement of 0.192 in. Thus, in all three checks the overtravel was found to be in excess of the specified maximum.

The sequence valve overtravel dimension was then measured with the bogie in the landing position (i.e. approximately horizontal) and found to be 0.291 in; the correct setting is 0.360 in minimum to 0.379 in maximum. A check of the sequence valve itself showed that the "cracking" clearance - that is at the point at which the valve opened to dissipate the backing pressure of 4 000 psi - was between 0.335 in and 0.326 in. Thus the sequence valve was so set that it remained "cracked open" with the bogie in the landing position.

The bolt that functions as a stop below the sequence valve operating crank was removed and the crank allowed to move further round to position against a bolt securing the sequence valve lever bracket. There was then a noticeable clearance between the crank and the sequence valve adjusting bolt, showing that the valve piston rod had extended fully; the overtravel dimension was found to have increased to 0.375 in. The landing gear was then selected 'up' and functioned normally.

The correct adjustment of the overtravel dimension of the sequence valve with the bogie at "tiptoe" depends upon:

(a) the bogie rotation jack being fully extended and locked;

(b) the striker plate on the bogie being deflected by the picketing lug and producing a clearance between the plate and the adjacent face of the bogie beam of 0.060 to 0.075 in (see Appendix 2).

A check revealed that the clearance was in excess of 0.140 in; this resulted in the striker plate roller imparting insufficient movement to the sequence valve actuating lever, which in turn led to incorrect setting of the overtravel dimension of the sequence valve. This incorrect setting would have been detected if the sequence valve setting had been checked with the bogie horizontal as required by the Britannia Series 300 Maintenance Manual, Section 3, Chapter 5, paragraph 51 (3) and (4).

An excess clearance between the striker plate and the adjacent face of the bogie beam, as noted above, is corrected by increasing the length of the rotation jack by screwing the eye out of the piston rod. When this was attempted it was found that the eye end of the jack assembly could be moved easily without loosening the locknut, which was wire-locked; the eye could be screwed out $\frac{1}{4}$ turn without disturbing the locknut. This was done and the bogie was returned to 'tiptoe'; the striker plate clearance was now found to be 0.110 in and the resulting overtravel dimension of the sequence valve 0.153 in, that is, less than the minimum where previously it had been more than the maximum.

The port and starboard rotation jacks were removed and tested on a hydraulic rig, to see if there was spiral action accompanying movement of the jack piston under hydraulic pressure which could alter the length of the jack and consequently the striker plate clearance and the sequence valve overtravel clearance. The starboard jack was found to 'spiral' through some 10° over the full stroke, but the port jack showed no such tendency. This may have been due to the interior of the port jack having been badly contaminated and the cylinder walls corroded, probably by the fluids used by the crew in the attempt to recharge the hydraulic system.

1.16 The sequence valve change on G-ANCG, 19/20 April 1967

At about 0400 hours on 19 April, G-ANCG returned to the maintenance base with an entry in the technical log-book that the port undercarriage sequence valve was leaking. The shift supervisor, who was also the inspector responsible for the work, arranged for a fitter to replace the faulty valve. By 0730 hours, when the shift ceased work, the new valve had been fitted but not adjusted.

The shift returned to duty at 2300 hours the same day, by which time the aircraft had been moved to a hangar where it was possible to put only the nose under cover; it had been jacked up to enable the undercarriage bogies to be rotated for a retraction test. The portable hydraulic rig normally used for retraction tests was not available, so the shift supervisor told a fitter to set up the new sequence valve using the aircraft's

hydraulic hand pump. The supervisor then had to leave to attend to other duties, and when he returned some 20 minutes later he found the port undercarriage bogie in the horizontal, i.e. landing position. He instructed the fitter to rotate it to the 'tiptoe' position. Then, with the bogie in this position, the supervisor checked the sequence valve clearances and made the adjustment he considered necessary in accordance with the Maintenance Manual, Section 3, Chapter 5, paragraph 51 (1) and (2) (quoted in Appendix 1). The radius rod safety pin was then removed and the port undercarriage made to retract, using the hand pump, to check that with the bogie at 'tiptoe' the main jack was being supplied with fluid water pressure. He did not cause the undercarriage to be fully retracted to the 'locked up' position as the wind was moving the aircraft on its jacks and he was anxious to have it lowered to the ground.

The port undercarriage was then lowered, the green lights illuminating showing that it was locked down, and the jacks were removed.

2. - Analysis and Conclusions

2.1 Analysis

The undercarriage retraction sequence valve has two positions - shut, when it directs fluid only to the bogie rotation jack, and open, when it directs fluid to the main retraction jack as well. The change-over is controlled by a pilot valve which moves up to allow the main valve to 'snap open'. This action takes place as the result of a very small movement of the pilot valve within its full range of travel.

After setting the clearance between the travel limiting nut on the valve piston rod and the adjacent valve casing with the bogie in the 'tiptoe' position, the engineer should then have lowered the bogie to the landing (horizontal) position and checked, in accordance with the maintenance manual, that sufficient clearance had been left for the piston rod to extend and allow the valve to shut. A check with the bogie lowered would have shown that in making the adjustment he had, in fact, set the valve so that it remained open with the bogie in the landing position. It would thus allow hydraulic pressure to both the bogie rotation jack and the main retraction jack and the latter, with its larger operating surface, would operate in preference to the former until resistance to movement of the main undercarriage leg developed; not until this happened would the bogie rotate. Thus, when the undercarriage was free to move only the main leg would operate, but with the locking pin inserted in the radius rod, as it was during the supervisor's ground check, the bogie would rotate as if the valve had been properly set.

The maintenance manual requires a check to be made of the clearance between the striker plate and the adjacent face of the bogie beam as a preliminary to setting up the retraction sequence valve. The failure of the engineering personnel to carry out this check created a situation conducive to further error. However, the possibility of malfunction would also have been detected if the undercarriage retraction test had been carried out from the landing position (bogie horizontal) with the radius rod locking pin removed. With the valve set as it was the leg would have retracted without the bogie having rotated, as it did at the post-accident test referred to in 1.14. It is appreciated that the work was carried out in conditions far from ideal; if the aircraft had been in a hangar and if the hydraulic test rig had been available, the possibility of error would have been smaller. To remove the already prepared aircraft to a hangar and to wait for the hydraulic rig to become available might have resulted in a delay to the service which the inspector, understandably, would wish to avoid. This may explain, but does not justify, the omission to follow the provisions of the maintenance manual.

The investigation has shown that, when the air crew selected undercarriage 'up' after take-off, the port leg retracted before the bogie rotated. The rear wheels of the bogie then came up against the inside surface of the nacelle; further movement of the leg was resisted and the bogie rotation jack then operated, rotating the bogie until it jammed against the head of the main retraction jack. This caused retraction to cease and the crew were left with a red 'not locked' warning light. They assumed this was a fault in the 'up lock' microswitch and recycled the undercarriage; however, the visual inspection after the third recycling which showed the doors were not properly closed should have indicated this was not so. Further, reference to the technical log would have shown that the sequence valve had been changed before the flight, introducing a possibility that the retraction difficulty might be related to the work which had been done. In the event, each operation of the undercarriage jammed the port bogie against the head of the retraction jack until the securing bolt of the shuttle valve for the main and emergency 'down' lines was broken. Thereafter, there was no means of locking the undercarriage down since selecting 'down' merely pumped the hydraulic fluid overboard through the broken connexion.

Since the accident, an addition has been made to the Company's operations manual drawing attention to the possible dangers of repeated recycling of the undercarriage if, on retraction, the 'not locked' warning lights remain on. The Company has also issued an instruction drawing the attention of its engineering personnel to the importance of following the proper setting up sequence and checking all the relevant clearances which condition the correct setting up of the retraction sequence valve.

2.2 Conclusions

(a) Findings

The documentation of the aircraft was in order and the crew appropriately licensed.

The aircraft was properly loaded and trimmed.

The port main undercarriage retraction sequence valve, which was replaced before the flight, was not correctly set up.

The undercarriage retraction test to check the operation of the sequence valve was carried out in such a way that the incorrect sequence of retraction resulting from the finding indicated in the previous paragraph was not detected.

When the undercarriage was retracted after take-off, the port bogie beam fouled the port main undercarriage retraction jack head.

'Recycling' the undercarriage resulted in the detachment of the main and emergency 'down' lines, and the loss of all hydraulic fluid and other fluids with which the system was replenished.

None of the undercarriage units could be locked down and all collapsed during the landing.

(b) Cause or
Probable cause(s)

The undercarriage failed to lock down due to loss of the hydraulic fluid from the main and emergency systems. This resulted from fracture of the hydraulic lines consequent upon fouling of the port undercarriage retraction jack head by the bogie through incorrect setting up of the retraction sequence valve.

Scheduled international
Take-off
Emergency condition -
precautionary landing
Other personnel - inadequate
maintenance inspection

ICAO Ref: AR/088/67

APPENDIX 1

Undercarriage Retraction Sequence Valve

Operation

The operation of the retraction sequence valve is as follows:

When the weight of the aircraft is off the wheels and the undercarriage selector lever is moved to the 'up' position, pressure is supplied to the bogie rotation jack and the bogie is rotated rearward by the extending jack until the bogie beam assumes a position almost parallel to the main leg; when fully extended, the jack locks internally and the beam is held in this position. During this operation, the bogie damper passes through the dead centre position and then assists the bogie retraction. As the bogie reaches the limit of its travel, the striker plate roller on the rear end of the bogie beam strikes a pivoted latch which in turn operates a sequence valve mounted on the rear part of the main leg. Pressure oil then enters the radius rod, releasing its internal lock, and the retraction jack which retracts and so moves the undercarriage rearward and upward into its nacelle.

Adjustment

The Britannia Series 300 Maintenance Manual sets out in Section 3, Chapter 5, paras. 49-53 the actions for adjusting the sequence valve and bogies. The following, particularly items (3) and (4), is of interest in this investigation.

Adjusting the retraction sequence valve

51. Having completed the operations in para. 50*, check and adjust the retraction sequence valve as follows:

(1) With the bogie retracted to the 'up' position, as in para. 50(3), and the valve actuating level in contact with the valve adjusting bolt, use a travel setting gauge, Part No. GE 2672, to measure the clearance between the travel limiting nut and the adjacent face of the valve housing (Fig. 19, detail B). This must be between 0.16 and 0.17 in.

(2) If adjustment is required, loosen the locknut and turn the adjusting bolt until the correct clearance is achieved. Tighten the locknut, taking care not to alter the bolt setting. Check that the safety hole in the bolt is now visible.

(3) Select undercarriage 'down' and operate the hand pump to rotate the bogie to the down position.

(4) Check that the sequence valve plunger has extended to produce a clearance between the travel limiting nut and the adjacent face of the valve housing of 0.360 to 0.79.

(5) Wire-lock the locknut and the adjusting bolt.

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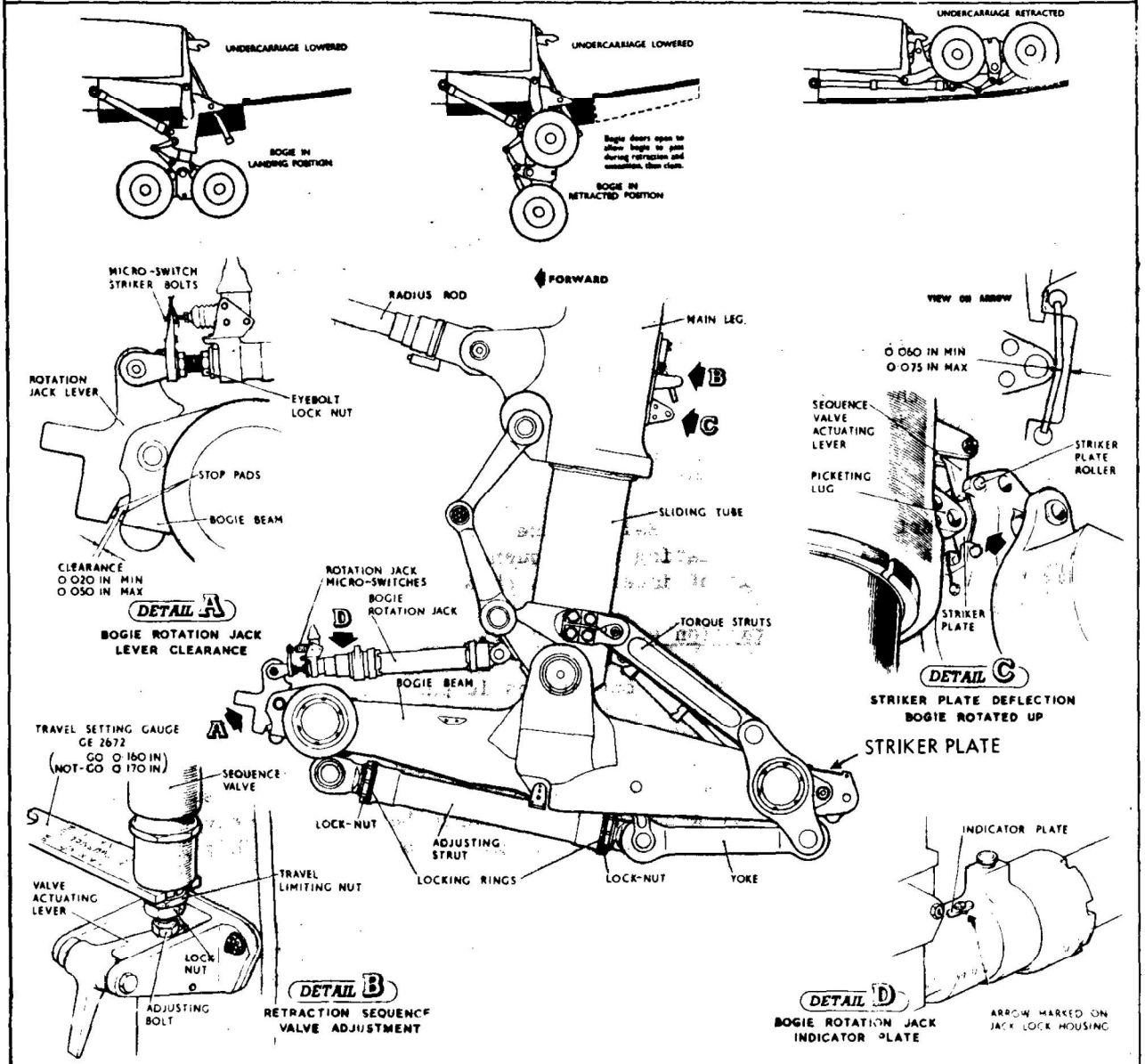
*This includes a requirement to check, and if necessary adjust, the clearance between the striker plate and the adjacent face of the bogie beam.

APPENDIX 2

ACCIDENT TO BRISTOL BRITANNIA 308, G-ANGA, OF BRITISH EAGLE INTERNATIONAL AIRLINES LTD., AT MANSTON AERODROME, KENT, UNITED KINGDOM, ON 20 APRIL 1967.



BRITANNIA MAIN LANDING GEAR