Aircraft Type and Registration:	Boeing 747-200, PK-GSE
No & Type of Engines:	4 Pratt & Whitney JT9D-7Q turbofan engines
Year of Manufacture:	1982
Date & Time (UTC):	8 April 1995 at 1615 hrs
Location:	London Gatwick Airport
Type of Flight:	Public Transport
Persons on Board:	Crew - 18 Passengers - 394
Injuries:	Crew - None Passengers - None
Nature of Damage:	Departure of outboard section of left inboard trailing edge fore flap, puncture to fuselage, damage to wing spoilers and mid flap
Commander's Licence:	Airline Transport Pilot's Licence (Indonesian)
Commander's Age:	39 years
Commander's Flying Experience:	10,595 hours (of which 4,244 were on type) Last 90 days - 169 hours Last 28 days - 61 hours
Information Source:	AAIB Field Investigation

History of flight

The flight crew were rostered to operate two sectors, Abu Dhabi - Zurich and Zurich - London Gatwick; their duty period started at 2340 hrs on 7 April when they reported for a scheduled 0040 hrs departure. The flight actually left Abu Dhabi at 0215 hrs and arrived at Zurich at 0910 hrs. The scheduled departure time from Zurich was 0810 hrs, however, the late arrival and a loose latch on the hydraulic reservoir access door on No 4 engine pylon further delayed the flight which eventually left Zurich at 1456 hrs.

The aircraft took off from Runway 28, at a weight of 260,159 kg (MTWA 350,000 kg), with 10° flap selected. Shortly afterwards, before climb power had been set, the crew felt a slight airframe vibration; this lasted for about 2 to 3 seconds. The flap retraction schedule progressed normally with the exception of a No 3 right leading edge flap amber 'in-transit' caption remaining on the flight engineer's panel; the flap was reselected to 1° and then UP, however, the flight engineer had to use the alternate flap switch to stow the flap and extinguish the caption.

A number of passengers in the rear cabin noticed small pieces of material coming away from the outboard end of the left inboard trailing edge flap (Fig. 1) and reported this to a cabin attendant. After the seat belt sign had been switched off the passengers' observations were relayed to the commander and, some time later, the flight engineer went into the cabin to inspect the area of the wing around the left inboard flap. At this stage the flap was fully retracted and there was no damage evident.

The flight continued uneventfully and the aircraft joined the intermediate approach to Runway 08 at London Gatwick Airport; the weather was good and was not a factor in this accident. The first officer was the handling pilot. The normal flap lowering schedule was carried out and the glideslope was intercepted at 3,000 feet amsl with the landing gear down and the flap at 25°. When, at about 1,300 feet amsl, the flap selector was moved to the 30° position, the flap remained at 25° and 'FLAP LD RELIEF' amber caption illuminated; the 30° flap limiting speed is 180 kt. The crew recalled that the airspeed was about 180 kt when the flap was selected as this was the airspeed imposed by ATC. The selection was made at this point in response to an ATC requirement to reduce the speed to 160 kt. At about 800 feet amsl the caption went out and the flap moved to 30°.

Indications on the flight deck of flap movement were normal, however, shortly after the flap position indicator had reached 30°, the crew felt a moderate airframe vibration and heard a loud bang. Lateral control appeared to become less positive and there was a tendency to bank left; no pitch control problems were experienced. There were no abnormal indications on the flight deck. The commander decided to allow the first officer to continue the approach and the aircraft landed safely at 1617 hrs. The crew were not aware of the precise nature of the problem and the flaps were retracted during the after landing check; they appeared to operate normally. The aircraft taxied to Stand 35 where it was shut down at 1622 hrs.

Passenger observations

Shortly after take off, small pieces of material were seen by passengers coming away from the outboard end of the left inboard trailing edge flap; the flap section appeared to them to be in contact with the high speed aileron as the aileron moved up and down. This was reported to the cabin attendant seated at the L3 door and, later, to the Purser.

The passengers who noticed the problem after take off made a point of watching the flap closely as it was extended during the approach. The mid and aft sections came out normally but the outboard end of the fore flap appeared to stick and the fore flap was lying at an angle over the mid flap. They saw the outboard section of fore flap suddenly give way and come off, making a very loud bang as it struck and punctured the fuselage skin.

Crew duty time

The crew had been on duty for over 16 hours 37 minutes when the aircraft landed. The relevant maximum flight duty period quoted in the company Operations Manual is 15 hours, however, the commander, having considered the possible stress placed on his crew, is authorised to exceed this maximum in the event of unforeseen technical or operational difficulties. After such an exceedence, the crew must be given 18 consecutive hours rest. These conditions applied to the accident flight and the crew were afforded the appropriate rest period. There was no evidence to suggest that crew fatigue contributed to the accident.

Flight Recorders

The Flight Data Recorder (FDR), a Sundstrand Digital Flight Data Recorder (DFDR), was removed and a satisfactory replay obtained. The Cockpit Voice Recorder (CVR) was also removed but it contained no useful information as the approach and landing had been overwritten on the 30 minute recycling tape.

After takeoff from Zurich the flaps were initially selected to UP at 6,700 feet (on 1,013 mb) at a speed of 244 kt. The FDR data showed that the leading edge flaps retracted but a leading edge flap in-transit signal remained ON. The flaps were subsequently selected to 1° and re-selected to UP at 15,000 feet at 250 kt but the in-transit remained ON. During the approach to Gatwick the selection of Flap 30° was recorded at 1,075 feet and at a speed of 178 kt and the flaps achieved the 30° setting at an altitude of 591 feet and at a speed of 164 kt. This coincided with a rudder and control wheel input by the pilot which would indicate that this was probably where the section of flap departed.

Engineering Investigation

After the aircraft had landed it was found that the outboard half of the left inboard trailing edge fore flap was missing. It had failed rearwards and upwards and its outboard end had hit the side of the fuselage at station 1820, at and just below the window level. It had indented the structure, caused a number of penetrations through the skin and had partially dislodged one of the windows and the internal cabin panelling. Some damage had also been caused to the wing as the fore flap had detached. The mid flap had an indentation in its leading edge and some structural damage where the fore flap support tracks, which are contained within the mid flap (Fig. 1), had been bent and broken. The inboard spoilers, located above the flaps, had some impact damage and the closure rib adjacent to the flap outboard end, which provides support for the high speed aileron, had suffered some abrasion, indentation and cracking. The debris which had fallen from the aircraft on the approach was found in an open field 3.5 km from the touchdown point on Gatwick's 08R runway close to the extended centreline. This material was recovered and taken to the AAIB HQ at Farnborough.

The inboard flap assembly (fore flap, mid flap and aft flap) deploys rearwards along two flap tracks attached to the wing. The mid flap rides on a carriage on each track and each mid flap carriage is moved by a screw jack to deploy the whole flap system. The aft flap is attached to the mid flap and is not relevant to this inquiry. The fore flap rides on a pair of sequence carriages also on the main tracks whose movement relative to the mid flap carriages is controlled by stops and detents. The fore flap is also tied to the mid flap by three sets of attachment fittings linked to support tracks which move between rollers within the mid flap. This system allows the fore flap to adopt the correct spacing and angle relative to the mid flap as the flaps extend. The detached portion of fore flap contained the location of the outboard sequence carriage attachment fitting. The fitting (Part No 65B39025-13) was found still attached to its sequence carriage on the aircraft . The inboard fitting was found intact on the aircraft with the inboard portion of the fore flap. The two outboard rail attachment fittings and support track assemblies had been ruptured but the inboard set remained intact on the aircraft with the inboard section of fore flap.

The investigation focused on the fore flap outboard sequence carriage attachment fitting and the reason for its separation from the fore flap spar. This fitting is part of the fore flap assembly and can only be removed from or attached to the fore flap when the top skin of the fore flap has been removed. From the aircraft records, it appeared that this had been last done when the fore flap was overhauled by an agent in 1991 during the aircraft's last 'D' check and the subject fitting (new) was used to replace the previous fitting which was worn.

The fitting was found with 1 bolt present (bent and trapped in its hole) out of the vertical array of 5 bolts which attached the fitting to the front face of the fore flap spar (Figs. 2 & 3). The corresponding holes in the fore flap's spar were empty. The trapped bolt was slightly bent and had some thread damage at its tail end but was otherwise intact. Another bolt was found lying loose on one of the wing lower surface panels in front of the fore flap, near the point at which the fore flap failed. From the dimensions of this bolt and from a chemical analysis of contamination on its surface, which matched fretting product found on the fore flap fitting, this was identified as the top bolt from the fitting. This bolt was intact and undamaged. Three bolts were, therefore, missing. Five nuts and five washers of the correct sizes were found within the fore flap when it was opened up during the investigation.

The attachment fitting and its location on the fore flap were liberally covered in a greasy black deposit. A chemical analysis of this showed it to be a mixture of grease and fretting product. Both the face of the fitting and the spar surface showed loss of primer and metal which indicated that the surfaces had been held together but with insufficient clamping load to prevent movement. Examination showed that all the bolts had been in position at one time with the nuts fitted, that the bottom bolt had been the first to become loose and be lost, the top bolt the second and that the remaining three bolts had been loose but retained, resulting in damage to their holes in the fore flap spar.

The nuts used on this fitting were type BAC N10JC ('JC nuts'). They are formed from sheet steel with a hexagonal lip and the threaded bore is ovalised to provide the locking effect. New nuts and bolts were used during assembly after overhaul. Most carried some contact evidence that they had been loaded by a spanner or socket in the tightening direction. The bottom nut (identified because its size was 5/16" whereas the others were 1/4') had suffered some impact damage on the outside lip after it had been last tightened. The direction of this damage was in the untightening direction. A rivet adjacent to the nut appeared to have been reworked and the damage to the nut may have occurred during that process. The larger size of the bottom bolt was a modification which was intended to increase security of the fitting rather than static strength. The nuts were required to be torque loaded to the standard torques for their diameters (50-80 lb.in. for 1/4" and 100-150 lb.in. for 5/16") but it was noted that the agent's work instructions quoted only the value for the 1/4" nuts; previous modification standards of this fitting had used only 1/4" nuts and bolts. The bottom nut/bolt make the largest contribution to the stiffness of the fitting's vertical attachment as they attach directly to the front spar's lower chord; the other nuts/bolts are attached to the web which is more flexible. (A vertical crack was found in the doubling flange behind the web.) All the evidence pointed to the bottom nut/bolt being the first to become undone.

The flap system on PK-GSE was examined to see whether there were any conditions present which could have resulted in excessive or unusual loading on the fitting. On the inboard fore flap carriage the front roller, which travels on the main flap track was found to have broken off from the carriage. The roller was found lodged in the wing structure in front of the flaps. The detachment of the roller from the carriage may have been a result of the carriage being twisted on the flap track as the fore flap was released at its outboard end but the roller's bearing had broken up and partially seized and the roller's outer surface worn into a number of "flats" and it had obviously been in that condition for some time. (When the flaps are extended past the 5° position, as they would be for inspection, the sequence carriage front roller sits in a detent notch in the flap track and its condition can only be determined by a particular and careful examination.) However this was not considered to have been a significant factor in the detachment of the outboard fore flap fitting. The tracks and rollers within the mid flap were found to be in good condition with no evidence of binding (Boeing Service Letter 747-SL-57-61-A refers). The carriage and fittings were last given an external visual inspection at the last Check 'C' in August 1993. If there was any indication of distress in the outboard fitting at the time of this check then it may have been the presence of fretting product around its location but the area is one that becomes dirty from the blow back of grease on the open surfaces of the tracks and carriages.

In addition to the location of the outboard sequence carriage fitting on to the front face of the fore flap spar the fitting has a flange which locates on the underside of the spar (Fig. 3). This lower flange had fractured but the four bolts which secured it were still intact and in place in the spar with the separated part of the flange. Most of the fracture was clearly overload with plastic deformation. There was one small area of fatigue at a bolt hole but this was considered to be secondary and due to the high bending loads suffered by the flange during the period after the front face bolts had become loose.

The outboard sequence carriage fitting and all the recovered components associated with it were examined in detail with the assistance of the manufacturer. The bolt which was found loose in the wing and is thought to be from the top position on the fitting was found to be low on pitch diameter and the "run-on" torque with the only undamaged 1/4" nut (thought to match this bolt) was found to be minimal. The holes at the top positions in both the fitting and spar were also found to be slightly oversize (the close tolerances to which these holes are drilled contribute to the security of the assembled fitting). The top bolt is thought to be the second to have become loose. Other quality checks showed no significant anomalies.

Though defects and anomalies described above may have had some contributory effect the investigation identified the shimming and security of the horizontal flange as the primary problem. There was evidence that there had been no shim present between the outboard sequence carriage fitting's horizontal flange and the underside of the fore flap as required in the fitting assembly drawing number 65B39011. In addition to showing that no shim was present, fretting damage on the flange face and the spar undersurface showed that they had been in only partial contact . Also the bolts in the horizontal flange were found to be at least 1 grip (shank) length too long. (They were all size 11. The specified size is 9±1 and 9 was the estimated required length obtained during the investigation.) Two of them showed some evidence that the nuts had been tightened against the thread run-out at the grip reducing their clamping effectiveness against the flange. As found, the bolts were not loose though the retained half-flange was loose under them. Their torque was not measured but there was a distinct breakout torque as they were untightened. Lack of security of the horizontal flange could allow the fitting to move under load (particularly the side loads which are all taken by the fore flap's outboard fitting) in such a way as could cause the nuts/bolts on the vertical face to lose their locking torque. Once their locking torque had been lost it is considered possible that the JC nuts could be "hammered" outward along the thread by the loosened fitting.

Summary

The outboard sequence carriage attachment fitting of the left inboard trailing edge flap had been fitted without the required shim under its horizontal attachment flange and with bolts through the flange which were at least one size too long. This resulted in the joint having less than the required clamping force. After some time in service, movement of the attachment fitting relative to the fore flap under flight loads resulted in fretting of the mating surfaces and eventual loosening and release of the five bolts securing the vertical face of the fitting. Fracture of the horizontal flange, weakened by a small area of fatigue, then released the fore flap from the outboard sequence carriage. Subsequent failure of the fore flap near its mid-span and rupture of the two outboard support tracks allowed the outboard section of the fore flap to detach.

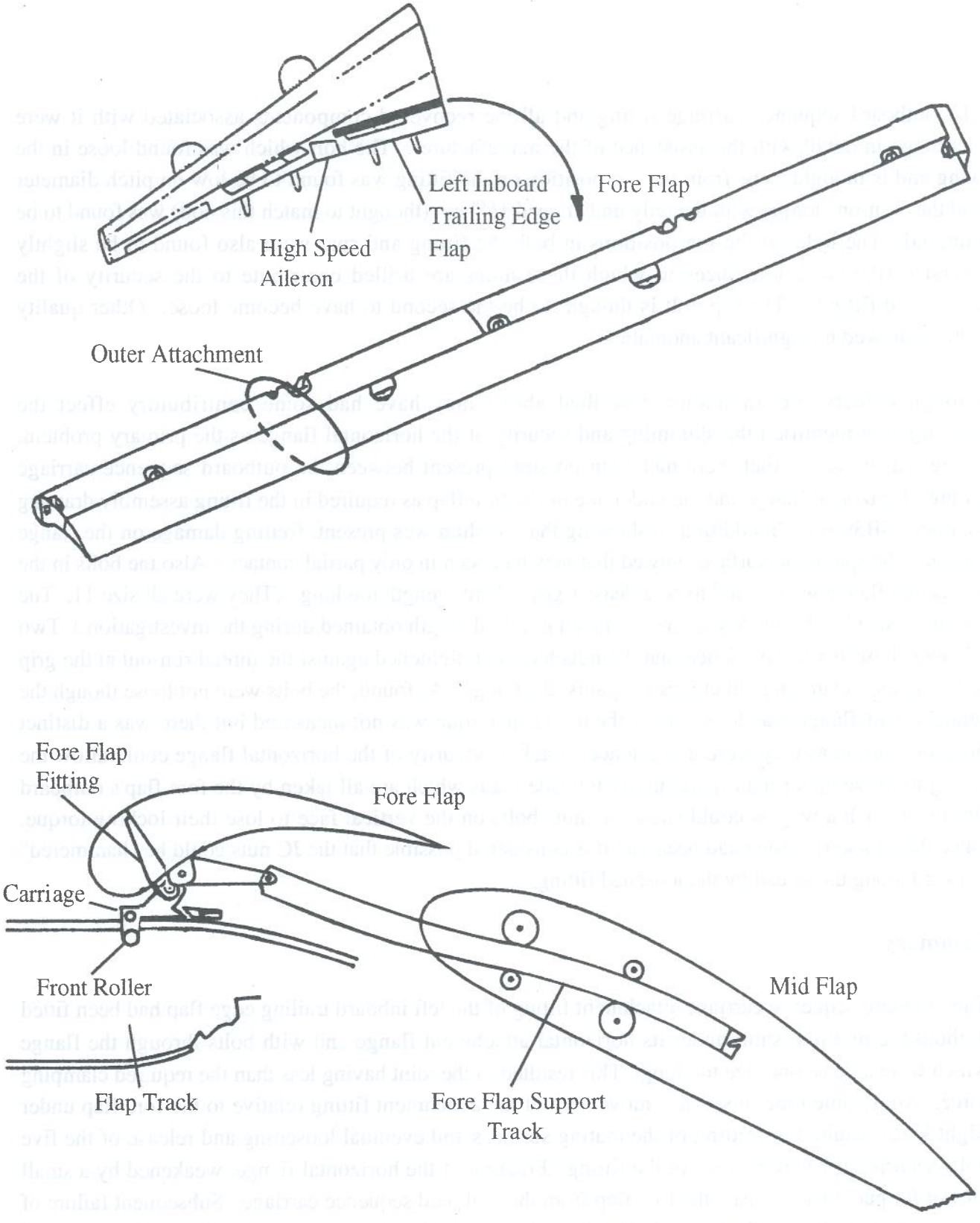

Fig. 1 - Trailing Edge Fore Flap Outer Support

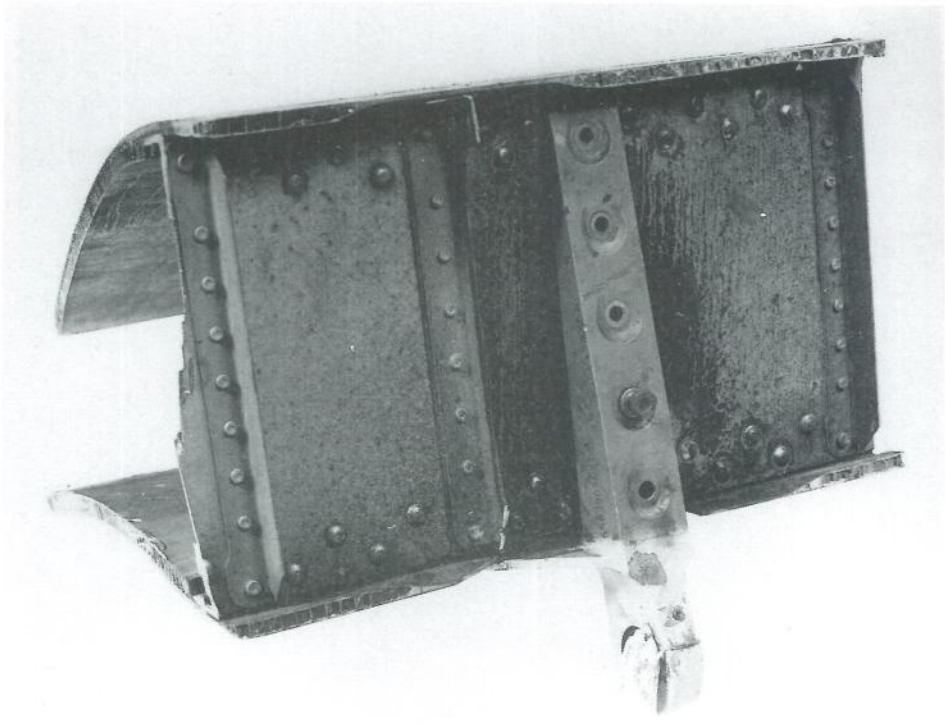

Fig. 2 - Fitting on fore flap spar (After fitting cleaned)

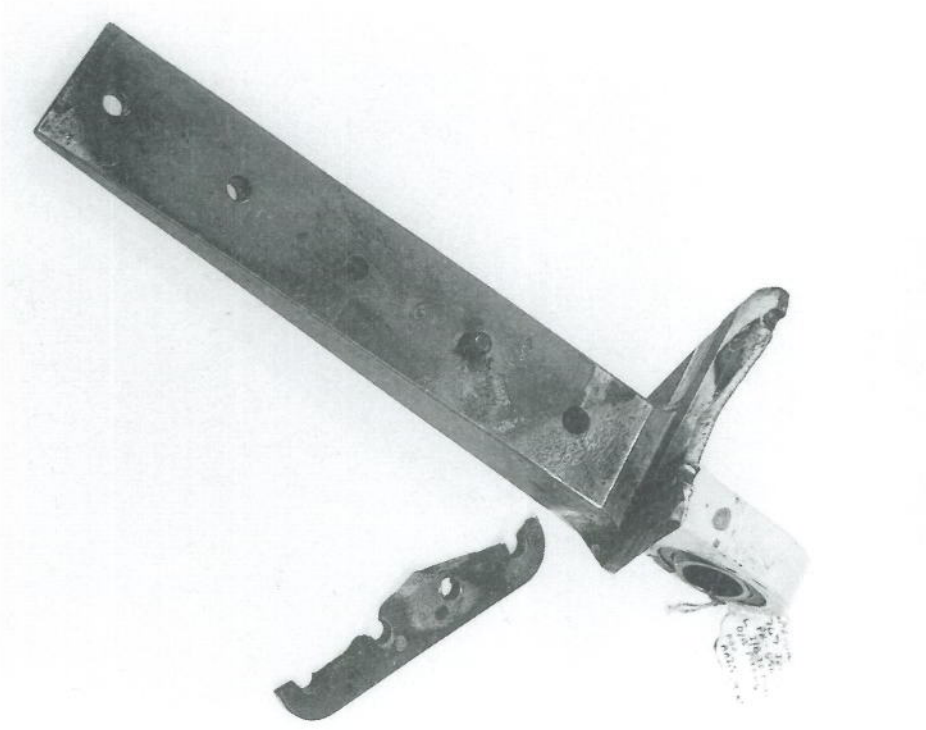

Fig. 3 - Fitting aft face and bottom flange (Showing fretting on both surfaces)