6250/77

Accident Investigation Unit
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R4/77

9 August 1977

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ACCIDENT TO GAZELLES XX 415 AND XW 859 OF 705 SQUADRON ON 13 JUNE 1977

1. The enclosed report is forwarded in accordance with JSP 318 2-5-0107.

2. Please acknowledge receipt of this report by signing the attached receipt form and returning it to the above unit.

[redacted]
Lieut Cdr RN
Officer in Charge AIU

Encl.

AIRCRAFT
ACCIDENT
INVESTIGATION UNIT

REPORT 14/77

SUBJECT [redacted]

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Accident Investigation Unit
HMS DAEDALUS
Lee on Solent
PO13 9NY.

AIU/R4/77

9 August 1977

ACCIDENT TO GAZELLES HT2 SERIAL NOS XX 415 AND XW 859 OF 705 SQUADRON ON 13 JUNE 1977

CREW: XX 415 - FLT LT R HOWLEY RAF (K)
LT CDR G A H BAILEY RN (K)

XW 859 - LT P BROWN RN (K)

CIRCUMSTANCES

1. Both aircraft formed part of the "Sharks" display team and were taking part in a formation flying practice in the Mounts Bay area at the time of the accident. FLT LT HOWLEY was flying XX 415 in the number four position and LT BROWN, XW 859 in the number six. At approximately 1234A whilst in a turn to port the two aircraft collided and fell into the sea. All three aircrew were killed. Two other aircraft in the formation incurred minor damage from collision debris.

2. The Accident Investigation Unit were called in at 1545A and a team arrived at RNAS CULDROSE by 1800A on 13 June.

INVESTIGATION

3. The details of the investigation are contained at ANNEX A. Briefly, an expeditious and highly successful salvage operation was mounted by DMS(N) and 99% of each aircraft was recovered and brought ashore by 17 June.

4. All control and service systems in both aircraft were extensively examined and found to have been functioning correctly. Both engines appeared to be operating correctly until impact with the sea. There was no available evidence of a bird strike on either aircraft.

CONCLUSIONS

5. It is concluded that both aircraft were serviceable in all respects and operating normally until the moment of collision.

RECOMMENDATIONS

6. There are no recommendations arising from this investigation.

[redacted]
Lieut Cdr RN
Officer in Charge AIU

ENCLOSURES: ANNEX A - Investigating Officer's Report and Photographs

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TECHNICAL INVESTIGATION INTO ACCIDENT TO GAZELLE HT2 SERIAL NOS XX 415 AND XW 859 OF 705 SQUADRON ON 13 JUNE 1977 BY LT [redacted] AND AA1 [redacted]

CIRCUMSTANCES

1. Gazelles XX 415 and XW 859 were being flown on the afternoon of 13 June in conjunction with four other aircraft in a formation flying practice of the "Sharks" display team, which is formed annually from instructors of 705 Squadron. The occupants of XX 415 were FLT LT R NO LEY RAF, pilot and LT CDR G A H BAILEY RN, passenger. LT P BROWN RN was the pilot of XW 859. At the time of the accident the aircraft were carrying out the second practice of the sortie over Praa Sands (O.S. Sheet 203 MR 580275).

2. At approximately 1234A the formation was in a left turn at 250 feet and 85 knots, having completed some 270° of a full circle towards the beach from the seawards direction. The disposition of the aircraft in the formation being as shown in FIGURE 1. At this point XX 415 and XW 859 (numbers 4 and 6 in the formation respectively) suffered in flight damage and subsequently fell into the sea. There were no survivors, the bodies of all three air crew being recovered from the sea some time later.

3. The assistance of the Accident Investigation Unit was requested at 1545A and an investigating team were flown to Culdrose, arriving at 1800A the same day.

ON SITE INVESTIGATION

4. Immediately after the accident, divers of 771 Squadron were despatched to the scene and, after recovery of the bodies, began locating and identifying the wreckage. It lay some ¾ nautical mile south of Praa Sands in approximately 60 feet of water. There were five major portions of wreckage, namely two fuselages, two engines, and a main gearbox.

5. As the salvage vessel was not due on task for the recovery until 15 June and bad weather precluded any further diving operations on 14 June, the investigating team commenced interviews with the surviving aircrew of the formation. The remaining aircraft of the formation were closely inspected for debris damage. The meteorological observations taken at the time of the accident were collected. As the formation flying was being carried out on a private Squadron frequency there was no record of any radio transmission except for a MAYDAY call from the formation leader after the accident at 1244A.

6. Meteorological Observations

Wind	360° 14 kts gusting to 30 knots
Visibility	8 km
Present weather	Haze
Cloud	⅛ Cu at 1000', ⅛ Sc at 2800', 8/8 As at 8000'
QFE	1001 Mbs
QNH	1011 mbs
Temperature	+ 11.7°C
Humidity	85%
Sea State	Slight to moderate
Swell	Short, low, confused
Sea Temperature	+ 15°C

INTERVIEWS

7. LT [redacted] (XW 856 - No 5) reported that .... 'after an uneventful practice at Culdrose the team began a second practice at Praa Sands. After an initial figure of eight over Praa Sands we turned towards the beach, the turn was quite normal, if anything slightly gentler than normal, at about 30° - 40° of left bank. Approximately 270° of the turn was completed and we were about to level out. I was formating on the left skid of No 4 (XX 415). Suddenly there was a 'puff' of white material, possibly perspex, coming away from No 4 or No 3, I heard No 3 (XX 391 - LT [redacted] call over the radio - 'my canopy has gone but I am still in control'. At the same time I saw No 4 shaking violently in pitch and roll and I was aware of a loud noise. I could see the left hand crew member being thrown about in his seat. It then dropped slightly, rolled left towards me and yawed nose right. I called 'Sharks break' and rolled left. Having checked that the airspace in front was clear I looked back at No 4, the aircraft appeared to be breaking up, the tail cone was drooping. I thought I saw a tailcone separated from an aircraft falling fin first. I then lost sight of the aircraft as I continued to roll left. At no time can I recall seeing No 6 (XW 859).

8. LT [redacted] (XX 319 - No 3) LT [redacted] confirmed that the prblem occurred approximately 270° around the last bend of the 'figure of eight'. However, his first intimation of trouble was a series of loud bangs 'like a machine gun, but louder' and his aircraft shuddered. He rolled right and as he did so he heard LT [redacted] call 'Sharks break', at the same time noticing holes in his canopy. Shortly afterwards Sharks leader called on the radio 'What's happened?', there was a pause so LT [redacted] said 'My canopy has gone but I can still fly'. He then flew straight to Culdrose and landed.

9. Due to the apparent discrepancy in the chronological order of events as recalled by LT [redacted] and LT [redacted] all the surviving aircrew of the formation team were interviewed. It was generally agreed that the sequence of events were as described by LT [redacted] namely a series of very loud, rapid bangs followed by LT [redacted] call of 'Sharks break' followed later by LT [redacted] call about his canopy.

10. Civilian Witnesses The accident was observed by a large number of the general public, mostly holidaymakers, in the Praa Sands area. After the accident they were interviewed by CDR [redacted] (Commander Flying Training, RNAS CULDROSE) and LT [redacted] (705 Squadron Instructor). The majority gave similar evidence of observing a collision between No 4 and No 6 in the formation, most probably No 6 hitting No 4, the minority thought No 4 might have 'Pulled up' and struck No 6. All agreed that the tail of No 4 appeared to fall shortly after the impact.

INITIAL INSPECTION OF AIRCRAFT

11. The remaining four aircraft of the formation were inspected for debris damage, the results were as follows:-

a. XW 856 (No 5) A cut approximately 3cm long was noted on the nose of the left hand main gearbox cowling. A dent was visible on the right hand side of the fin and there were scratches on the tail rotor drive shaft and rear servo control rod. There was a small hole in the outboard face of the upper right hand vertical stabiliser. Scratches were noted on the underside of the red main rotor blade in the area of the trim tab, and the upper surface of the yellow blade.

There was no evidence to suggest the nature of the objects that had caused the damage.

b. XX 391 (No 3) There was no significant debris damage to this aircraft other than holes in the canopy and left and right rear doors. Close inspection revealed that an object had entered the cockpit through the left rear door, pieces of shattered perspex still being present on the floor of the cockpit and the rear seat. The object then struck the rear door forward support frame and separated into 4 pieces, two portions breaking through the front left panel of the canopy, one through the right front panel and the fourth through the right front door. From measurement between the entry hole and the impact mark on the port rear door frame the angle of entry was calculated to be 14° 2' to the vertical plane of the door and 15° 31' below the horizontal plane, i.e. very fine on the aircraft's port quarter. A small amount of metal shavings recovered from the cockpit were analysed by MARL and found to be of a material consistent with the lead/antimony anti-node balance weight, contained within a Gazelle main rotor blade leading edge, a number of these having been found on the sea bed near the wreckage. It was considered that an item of this nature has the necessary density and would possess the energy required to produce the damage noted.

c. XZ 825 (Leader) and XW 854 (No 2) There was no significant damage to these aircraft.

SALVAGE

12. The salvage of the wreckage was carried out on 15 June by Director of Marine Services (DMS) divers working from RMAS PINTAIL, the investigating team being present on board. As stated in paragraph 4, the wreckage was in five major parts. When they were recovered from the sea bed it could be seen that the majority of both airframes had been recovered (PHOTO 1). The PINTAIL then sailed for Devonport and the wreckage was off loaded on 17 June. The wreckage was transported by road to Lee on Solent for detailed examination.

DETAILED INVESTIGATION

VISUAL EXAMINATION OF BOTH AIRCRAFT

13. On arrival at Lee on Solent the remains of the two aircraft were placed in a hangar in approximately the same position as they had held in the formation, namely XV 859 (No 6) to the right of, and behind XX 415 (No 4) (PHOTOS 2 & 3). The results of the visual examination are summarised below.

14. XX 415 (No 4) The wreckage as recovered was found to consist of the main fuselage with the rear structure still attached, although badly damaged. The main gearbox, together with main rotor head and blades, had detached from the airframe and were recovered separately as was the engine. The aircraft was subjected to detailed examination as follows:-

a. Crew Compartment This was badly damaged, all perspex panels and the roof panel were missing. The access doors were severely damaged with the exception of the left front door which had been jettisonned prior to the aircraft impacting the sea. The lower structure and instrument panel were intact but badly damaged. It was noted that the battery access panel situated in the nose of the aircraft had been

deformed around the battery by water impact. The condition of the front of the aircraft was consistent with a high speed water entry with the aircraft in a nose down attitude.

b. Seats and Harnesses Both pilots seats had been detached from the cockpit floor, they were recovered separately. The left hand seat had torn out of the cockpit decking in the area of its right front mounting and the left seat adjustment slide had failed in an upwards and rearwards direction. The right hand seat front mountings had both torn out of the decking and the anti-g retaining bracket had failed. The seat pan was badly distorted. The harnesses were intact and in reasonable condition.

c. Central Structure This was intact although the transmission support panel had detached from the forward bulkhead and had been deformed rearwards, the bulkhead had been pushed into the fuel tank area. The front gearbox mountings had been torn out of the transmission decking, the remains of the gearbox rear supports were still attached, having failed in tension approximately midway between the gearbox and transmission decking. The right hand centre section skin panel had detached, exposing the interior of the fuel tank, the panel being recovered separately. The panel had a series of parallel strike marks which corresponded with marks on the rear section right hand side, this indicating the marks had been made before detachment of the panel. The marks were consistent with light contact by a sharp metal object. There were eleven marks at an angle inclined upwards towards the main rotor disc (PHOTO 4).

d. Rear Structure The rear structure was badly dented and buckled on the right hand side between the second and third frames, it was virtually detached at the third frame by tearing consistent with the tail having moved to the right. The whole structure was still attached to the fuselage by the yaw control cables, the rear servo hydraulic pipelines, and the communication aerial leads. A series of black stripes were visible on the 'dayglo' paint within the damaged area (PHOTO 5). Comparison with the black material from which the skid of the gazelle tail fin is made showed a marked similarity in the pitch of the material to the disposition of the stripes (PHOTO 6). The left and right hand stabilisers were intact but the fin was badly damaged. The fenestron was also severely damaged, the horizontal drive shaft had failed at the third frame and had been pushed forward approximately 7.5 cm. The rear servo control rod had failed in tension at its attachment point to the rear quadrant.

e. Main Gearbox and Rotor Head Examination showed that the gearbox had been torn off rearwards. All three servo jacks were still attached to the gearbox casing. On inspecting the main rotor head it was noted that the non-rotating star and scissors were undamaged as was the rotating star assembly. Visual examination showed the spherical bearing to be in good condition. The droop stop ring had detached from its supports and was lying on the rotating star. The red main rotor blades pitch change rod had failed in tension and the blade had turned completely over, the spindle could not be turned. The flapping hinge was operating smoothly, the flapping (coning) stop had broken off and the oil reservoir was missing. The droop stop had also failed. The blue blade pitch control rod was still intact but badly bent, the flapping hinge was still operative but the flapping stop had failed and the oil reservoir was missing. The droop stop was badly marked.

The yellow blade pitch change rod was intact, the spindle bearing in good condition, the droop stop and coning stop had both failed. The oil reservoir was missing. The flapping hinge was in good condition.

f. Main Rotor Blades The red blade was measured and found to have lost 0.4 metres of the blade tip; it had split open along the complete length of the trailing edge. There was a large impact mark on the underside approximately mid-way along the length of the blade which had broken through the leading edge. The drag damper was still attached and appeared undamaged. The blue blade had lost 1.3 metres of its total length at the blade tip. The whole of the underside was completely missing exposing the inner core. Small fragments of the blade underside were recovered amongst the floating wreckage after the accident. The drag damper was intact and was undamaged. The yellow blade was measured and found to be 4.735 metres, having lost a small amount of its full length of 4.8 metres. The leading edge abrasion strip was still attached but badly damaged, there was an area of damage which appeared consistent with an impact with another blade leading edge approximately at right angles to the blade span. The blade was split open along the whole length of the trailing edge but the contours of the blade were still basically intact. The drag damper was still attached and in good condition.

g. Engine As stated earlier the engine had detached from the airframe and was found some distance from the main wreckage. The mounting frames were still intact, the drive to the gearbox had been torn off at the coupling. There was an area of deformation along the whole length of the engine at the three o'clock position. The engine was taken to Rolls Royce, Leavesden, for strip examination (paragraph 23 refers).

15. XW 859 (No 6) The wreckage as recovered consisted of the main fuselage with rear structure attached, and the main gearbox with rotor head and blades. The engine had detached from the airframe and was recovered separately. Close examination of the wreckage revealed the following:-

a. Crew Compartment This was badly damaged, all perspex panels had broken and the roof panel was missing. The battery access panels in the nose area, the air intake, and the instrument panel were intact and in remarkably good condition. The lower structure was basically intact. An area of deformation consistent with water impact was observed on the external panels of the lower structure.

b. Seats and Harnesses Both pilots seats were still attached to the cockpit decking, the left hand seat was badly damaged, the seat back being forced down over the seat pan. The right hand seat was less damaged although exhibiting an impact mark on the left hand edge of the seat back. The harnesses of both seats were in reasonably good condition. Those in the right hand seat showed impact marks in the area of the quick release box consistent with the occupant being thrown to the right at impact.

c. Central Structure The forward bulkhead was badly damaged and deformed forwards on its left hand side. The major part of the left hand skin panel was missing exposing the interior of the main fuel tank. Some irregular impact marks were visible on the lower part of the panel (PHOTO 7). The left hand skid had broken completely through

and the front portion had been forced upwards over the transmission decking. This, the water deformation along the left hand side of the lower structure, and the lack of damage to the nose structure was consistent with a high speed water entry in a straight attitude, left wing low with the aircraft pointing approximately 90° to the direction of flight. The transmission decking and the main gearbox were intact but badly damaged.

d. Rear Structure This was virtually detached from the remainder of the airframe by an area of damage between frames 1 and 2 consistent with the rear fuselage tearing to the right. It had also detached from the transportation joint by the shearing of almost all of the rivets, it was still attached to the main structure by control cables, tail servo hydraulic pipelines and communication aerial leads. The fin was in reasonably good condition with only light damage to the upper fairing. The fenestron duct showed evidence of a heavy blow to the base of the fin in an upwards direction, followed by distortion to the right. Damage to the tail rotor blades and cuts in the skin of the duct showed that the damage occurred whilst power was applied to the tail rotor (PHOTO 8). The tail rotor drive shaft and yaw control cables were intact up to frame 1.

e. Main Gearbox and Rotor Head The gearbox was still attached to the transmission decking and all three servo jacks were attached. The main rotor head spherical bearing and azimuth star assemblies were in good condition. The droop stop ring had broken free and was lying on top of the rotating star. The red blade pitch change rod was intact, both flapping and spindle bearings were operative. The flapping (coning) stop had failed and the oil reservoir was missing. The drag damper had failed in tension at its attachment to the blade sleeve. The blue blade pitch change rod had failed in tension, the blade having turned completely over and jammed. The flapping hinge was in good condition, the flapping stop had been forced inwards but was still intact, the oil reservoir was missing. The drag damper had failed in tension at its attachment to the blade sleeve. The yellow blade pitch change rod was intact and the flapping hinge and spindle were still operative. The flapping stop and reservoir were intact but the stop was badly marked. The drag damper was still attached to the blade sleeve, but badly cracked at the attachment arms.

f. Main Rotor Blades The red blade was measured and found to have lost 0.9 metre at the blade tip. The leading and trailing edges were split open but the general contour of the blade chord was undamaged. The blue blade showed a marked similarity in damage to the red, it had lost 0.6 metre of its blade tip. The yellow blade was also in similar condition, it had lost 0.4 metre of its tip.

g. Engine As stated earlier the engine had detached from the airframe and was found lying very close to the main fuselage. The support frame had failed at their attachment to the engine casing and the complete gimbal ring together with a portion of the clutch assembly housing was missing. The engine was taken to Rolls Royce, Leavesden, for strip examination (paragraph 23 refers).

16. Analysis of the Results of the Visual Examination Despite considerable secondary damage to both airframes, some salient features relevant to the accident were noted as follows:-

a. XX 415 (No 4) There was evidence of light blade tip contact, probably by the 'nib' on the extreme end of a blade tip, on the right hand centre section. It was considered that the most likely sequence of blade strikes was upwards and into the main rotor disc. Two main rotor blades had suffered damage to their undersides. All three coning stops had failed, showing that at some time during the accident, or the descent to the water that followed it, the rotor disc had 'cone up'. The evidence of heavy contact between the base of the fin of XV 859 and the rear section of XX 415 would seem to explain the evidence of most witnesses that the tail had failed in flight. It is considered that, following the severe damage to the main rotor blades, an excess in torque at the tail rotor would exist for a short period of time, this would normally have the effect of yawing the aircraft nose left. However, in the case of an already weakened rear section it is considered probable that the structure would fail to the right instead.

b. XV 859 (No 6) The irregular contact marks on the left hand skin panel of the centre section would appear to have been caused by a flailing rotor blade tip. It was significant that the damage to the main rotor blades was confined to the blade tips and the damage to the drag damper indicated that the blades had been subjected to heavy decelerative forces in flight.

There was no evidence to suggest which aircraft had moved out of formation and struck the other. It was decided, therefore, to examine all systems of both aircraft for evidence of any malfunction that may have caused the accident. The results of these examinations are given below.

17. XX 415 (No 4) Flying Controls The flying controls systems were subjected to detailed examination as follows:-

a. Collective The collective pitch lever assembly was badly damaged but both levers were still attached to the connecting shaft. There was a failure in the forward eye end of the semi rigid rod between the connecting shaft and the mixing unit. Microscopic examination of the fracture face showed characteristics consistent with an overload failure.

b. Cyclic The co-pilot's cyclic pitch control lever was found to be still attached to its connecting shaft, the pilots lever had broken off but was still retained by electrical leads situated inside the tubular section. The left hand inter-connecting rod had fractured due to an overload bending failure.

c. Pitch and Roll Channel Actuators Both stability and augmentation system (SAS) actuators had failed in overload at the tubular section and the roll channel actuator eye end was bent. The actuators and magnetic brakes were removed for bench testing (para 22 refers).

d. Lateral and Longitudinal Stop Assembly and Mixing Unit The cyclic linkage assembly and the collective linkage was intact and both stops were intact although severe 'hammering' of the forward stop and right hand stop was observed. The mixing unit was completely detached from the airframe and badly bent; all bell cranks were operative and all bearings were working smoothly. The vertical control rods were bowed and all three had failed in overload at the eye ends to the control bellcranks on the transmission platform.

e. Control Bellcranks and Servo Jacks The bellcranks had all broken free from the cross tube but were still attached to the servo jacks on the main gearbox. The right hand servo jack pilots input lever had sheared and the pilot valve had been pulled out of its sleeve. The servo jacks were removed for strip examination (paragraph 19 refers).

f. Yaw Control System The rudder pedals were still present and attached to the connecting rod, the whole rod being bent rearwards on the right hand side. The yaw damper connection to the connecting rod had failed in overload, the yaw damper, yaw damper switch and yaw actuator were removed for testing in conjunction with the Stability Augmentation System. The forward quadrant was intact but the right hand nylon stop was missing. The yaw control cables were inspected for correct routing and damage, there were no unserviceabilities. The rear quadrant was intact but the connecting rod to the tail rotor rear servo had failed at the eye end connecting the rod to the quadrant. The fracture was characteristic of an overload tensile failure and entirely consistent with the damage to the tail rotor assembly. The tail rotor rear servo was removed for testing in conjunction with the primary servo jacks.

18. XW 859 (No 6) Flying Controls The flying control systems were closely examined as follows:-

a. Collective Both collective pitch levers were intact and still attached to the connecting rod. The semi-rigid rod to the mixing unit was still intact.

b. Cyclic The cyclic pitch levers were intact and still connected to the cross shaft, the forward bellcrank was in good condition.

c. Pitch and Roll Channel Actuators The pitch and roll actuators of the SAS were still attached although badly bent, they and the magnetic brakes were removed for bench testing (paragraph 22 refers).

d. Lateral and Longitudinal Stop Assembly and Mixing Unit Both stop assemblies were intact and no 'hammering' of the stops was observed. One rod of the lateral system had failed between the stop assembly and the mixing unit, the fracture face showing characteristics of an overload bending failure. The mixing unit was intact but badly buckled, all bellcranks and bearings were in reasonable condition. The vertical control rods were badly bent and all three eye ends had failed in overload at their attachment to the control bellcranks.

e. Control Bellcranks and Servo Jacks The bellcranks on the transmission decking were intact and all rods were still attached to their respective servo jacks. All the primary servo jacks were still attached to the gearbox, although badly bent. They were removed for rig testing (para 20 refers).

f. Yaw Control System The rudder pedals and cross shaft were undamaged. The yaw damper and switch were undamaged and were removed for testing in conjunction with the yaw channel actuator (paragraph 22 refers). The yaw control cables had failed approximately 15 cm behind the forward quadrant, microscopic examination showed the failure to be due to tensile overload. The remainder of the cables

were checked for correct routing and damage - there were no unserviceabilities. The rear quadrant was undamaged as was the connecting rod to the tail rotor rear servo jack. The rear servo jack was removed for rig testing.

19. XX 415 (No 4) Servo Jacks The main servo jacks and rear servo jack of XX 415 were taken to A and AEE Boscombe Down where testing facilities were available. Due to extensive secondary damage only one main servo jack and the tail servo jack proved suitable for rig testing. The remainder were subjected to strip examination, the results were as follows:-

a. Left Servo Jack Ser. No. 648-T-913 This jack was found to be in a suitable condition for rig testing. The jack range of movement was found to be correct at 12.5 cm. The force required to move the pilot valve with hydraulic power on was in limits of 0.4 lbs. With hydraulic pressure off, the load required to move the servo jack mannually was within limits at 9 lbs. The by-pass valve and input lever lock operated at 140 psi on hydraulic pressure decrease and unlocked at 200 psi on hydraulic pressure increase. The jack velocity was correct at 1 second per stroke. The jack was stripped to provide a suitable comparison with the remainder of the servo jacks.

b. Right Servo Jack Ser. No. 648-T-884 The piston of this jack was too badly bent to allow rig testing. It was then subjected to strip examination. The main piston was bent at its lower attachment but no scoring of the piston was evident. The piston seal was in good condition and no defects were found within the main cylinder bore. The upper and lower end caps which secured the piston within the jack body were in good condition as were the seals. The pilots input lever had sheared from the retaining bolt and the pilot valve had been forcibly withdrawn from the pilot valve sleeve, there was some evidence of corrosion on the valve and it exhibited a bright score mark at its furthest end consistent with forcible removal from the pilot valve sleeve and end cap. The by-pass and input lever lock assembly was in good condition. There was no evidence of pre-impact malfunction.

c. Forward Servo Jack (Ser. No. 648-T-933) As stripped the jack revealed no pre-impact abnormalities internally. However, severe brinelling and corrosion of the input lever lower pivot bolt (AP 1010-0901 to 0904-1A Chap 20-21 Fig 1 Item B) was noted. It was considered that this brinelling and consequent erratic operation of the pivot could lead to servo jack instability (paragraph 25 refers). The input lever from the two other servo jacks were inspected, no evidence of brinelling was found.

d. Tail Servo Ser. No. 675-T-292 As already stated this servo was in a suitable condition for rig testing. It proved to be within specification for range of movement, by-pass and input lever lock operation, also manual input and pilot valve load test. It was noted that the input lever range of movement stop (AP 1010-0901 to 0904-1A Chap 20 Fig 2 Point A) was bent and the lock washer at the piston eye-end was severely hammered. The piston rod was bent at the point where it passes through the tail rotor gearbox, the damage being entirely consistent with distortion on the rod due to impact damage causing tension on the input lever stop and forcing the lock washer against the body of the servo jack.

20. XJ 859 (No 6) Main and Tail Servo Jacks None of the main servo jacks of this aircraft was capable of rig testing. The results of the strip examination were as follows:-

a. Front Servo Jack Ser. No. 648-P-66 The piston rod was badly bent but the piston and seal were both in good condition. The cylinder bore and end caps were unmarked. The input lever lock and by-pass were in good condition. There was no evidence of pre-impact malfunction.

b. Left Servo Jack Ser. No 648-P-345 Again the servo jack had a badly bent piston rod. All seals and internal bores were in good condition and there was no evidence of pre-accident malfunction.

c. Right Servo Jack Ser. No. 648-P-48 This servo jack was found in a similar condition to the other two. There was no evidence of pre-impact malfunction.

d. Tail Servo Jack Ser. No. 675-R-180 The tail servo jack was tested on the hydraulic test rig and was found to be within specification It was observed that the lock washer securing the eye-end of the piston rod at the input lever end had failed at the securing lugs and had rotated through approximately 30°. The lock washer was removed and closely examined, the securing lugs had failed due to twisting of the piston rod which had occurred when the rear servo jack was being removed from the tail rotor gearbox by the investigating team. It was not considered significant to the accident.

All three main servo input lever pivot bolts were removed and examined; they all exhibited signs of wear with the very early stages of brinelling evident as noted in paragraph 19c above.

21. Hydraulics As neither aircraft was to Post Mod 5302 standard there was no warning facility for hydraulic system failure on the centralised warning panel, and therefore no possibility of confirming hydraulic system serviceability at the time of the accident by microscopic examination of the bulb filament. The hydraulic tanks from both aircraft had broken off the front of the gearbox at the mounting flange to the power pack. The hydraulic tanks had been recovered separately, they were subjected to close examination, no defects were observed. The hydraulic power packs were removed to check the condition of the 'weak links', they were both intact. On removal of the servo jacks from both aircraft salt water under pressure was found in the hydraulic pressure pipe lines to the jacks indicating that the hydraulic pumps had continued to operate for a short period after hydraulic tank rupture and immersion in the sea.

22. Examination of SAS Installations The following components of both aircraft were removed for examination and possible Standard Serviceability Tests (SST) at A AEE Boscombe Down:-

a. Roll, pitch and yaw computers
b. Roll pitch and yaw actuators.
c. Roll and pitch magnetic brakes.
d. Airspeed switches
e. Hydraulic damper actuator yaw channel switch assemblies.
f. Control switch boxes.

Damage due to water impact was minimal. Salt water corrosion damage was evident in all components. Insulation resistance was low on all components. Ultrasonic cleaning and drying was carried out on the computers, actuators, airspeed switches and control switch boxes but failed to restore the insulation resistance to an acceptable level (meaningful SSE's were therefore not possible). Strip examination of the computers showed the printed circuit boards, general wiring and chassis to be in reasonable condition; their gyro spin motors, however, did not run when put on test and were found to be seized by corrosion products. Strip examination of the actuators showed either the actuator motors or linear gearing to be seized by corrosion products. The adhesive, fixing the stationary pick off strip, of the feedback potentiometer, to the actuator arm barrel, had failed on all items. The 'as found' positions of the actuator rod assemblies were as follows:-

a. XX 415 (No 4)

	Mid Position (mm)	As Found Position (mm)	Total Travel About Mid Position (mm)	As Found Travel (mm)
Pitch	12.5	11.4	± 3.5	1.1 retract
Roll	12.5	9.8	± 4.5	2.7 retract
Yaw	13.0	14.0	± 8.0	1.0 extend

b. XW 859 (No 6)

Pitch	12.5	10.0	± 3.5	2.5 retract
Roll	12.5	13.0	± 4.5	0.5 extend
Yaw	13.0	13.0	± 8.0	Mid

The airspeed switch brackets showed signs of impact damage. Both switch covers were removed, the switches then cleaned out and oven dried. No defects were apparent although the solder on the aneroid capsules had melted during the oven drying period. The pitot orifice of XW 859's switch was completely blocked with corrosion products. The hydraulic damper actuator yaw channel switch assemblies were seized by corrosive action. The micro switches operated satisfactorily when the piston assemblies were dismantled for inspection. No other defects were found. The control switch boxes were intact but all switch toggles had been bent upwards. The SAS engage switch of XX 415's switch box did not hold on correctly, otherwise all switches were operable. The switch positions as found were as follows:-

XX 415 (No 4) - SAS engage, roll servo - OFF
Pitch and yaw servo - ON

XW 859 (No 6) - All ON

Damage to the SAS components was wholly consistent with impact and subsequent salt water immersion. No evidence was found to suggest any pre-accident malfunctions or defects in the SAS installations fitted to either aircraft. The circumstances of the accident preclude any positive identification of the condition of the respective SAS installations prior to impact. The

evidence of the 'as found' position of the actuator arms and control switches suggests that in both aircraft the SAS was engaged during the flight and remained operative until each aircraft impact with the sea.

23. Engines Both engines were taken to Rolls Royce Small Engines Division, Leavesden, for strip examination. The results were as follows:-

a. Astazou Ser. No. 4151 (XX 415) The engine was subjected to close external examination. There was an area of damage to the oil tank, external pipelines in the area between the axial and centrifugal compressors and the turbine shrouds. The damage was confined to the 5 O'clock position on the engine, and appeared consistent with water forming on impact. The engine support frame was still attached, having failed in overload at the airframe connections. The gimbal ring was present, disconnection at the gearbox having occurred at the attachment pins. The main fuel pipelines had failed in tension at the airframe attachment. There was severe 'chewing' of the gimbal ring and the torque transmitter block consistent with high rotational speed at the time of disconnection from the gearbox. When stripped, the three turbine discs showed evidence of tip contact with their adjacent turbine shrouds. The rub on each shroud had occurred at the approximate 4 O'clock position and showed evidence of high rotational speed on impact. There was some evidence of slight foreign object damage to three blades of the axial compressor and approximately one third of the first stage diffuser vanes were bent inwards and rearwards by the ingestion of water. The fuel control system was stripped and found free of defects, the fuel cut-off valve was found in the open position. In discussion with Rolls Royce it was considered that the evidence noted during the strip investigation was consistent with the engine becoming detached from the airframe immediately prior to or at water impact, whilst still rotating at high speed.

b. Astazou Ser. No. 4084 (XW859) When subjected to external examination it was noted that the exhaust duct was badly crushed, the free wheel output shaft had detached at the clutch and a large section of the clutch housing had broken away; the engine mounting frames had failed at the fixing bolt to the engine casing. Strip examination revealed several blades of the axial compressor to be bent against the direction of rotation and vanes on the first row stator were bent rearwards and inwards. The axial compressor shaft had sheared at the rear where the driving sleeve locates with the splines (AP 101C-0901 to 0904-1B Chap 40-81 Fig 16, items 1 and 2). The splines were twisted off in the direction of rotation. The splines of the centrifugal shaft had also twisted (item 7) within the driving sleeve (item 6) but had not sheared. The failure pattern was consistent with rapid arrest of the axial compressor while being driven by the turbines. The fuel control unit was stripped; no defects were found and the fuel cut off valve was found in the open position. It was considered that the damage to this engine was consistent with high speed and high power being developed by the engine at water entry.

24. Aircraft History The relevant details of the aircrafts' history was as follows:-

a. XX 415

DATE	AIRFRAME HOURS	REMARKS
19.11.75	Nil	Constructed WHL, Yeovil
26.11.75	3.15	Transferred to RNAY ROUGHTON
8.1.76	4.40	Transferred to 705 Squadron
1.7.76	212.35	Torque liaison shaft No WAC 527 removed - loose rivets. Shaft No WAB 15 fitted.
2.8.76	269.40	Clutch Ser. No. WAC 671 removed - worn Clutch Ser. No. WA 162/R1 fitted.
7.5.77	573.35	Main rotor blade Ser. No. 2302 removed - in flight tracking problem. Blade Ser. No 825 fitted.
13.6.77	590.30	Accident occurred.

b. XZ 859

9.73	Nil	Constructed WHL Yeovil
17.9.73	5.05	Transferred to RASU Culdrose
12.3.74	10.15	Transferrred to 705 Squadron
15.5.75	120.30	Tail Servo Ser. No. Q-127 removed - Servo Ser. No. R-180 fitted.
13.6.75	120.30	Main rotor head Ser. No. 142 removed iaw MOD UK(N) 1212372 JUNE. Rotor head Ser. No. M377 fitted.
14.7.76	316.10	Torque liaison shaft Ser. No. WA 33 removed - suspect cracks at window. New shaft WAB 9 fitted.
17.1.77	546.45	Astazou 4073 removed life expired. Astazou 4084 fitted.
10.3.77	590.30	Tail rotor hub Ser. No. M133 removed - blades eroded. Hub Ser. No. M418 fitted.
6.5.77	651.55	Main rotor blade leading edge strip delaminating - all blades removed. Main rotor blades Ser. Nos 108, 1096 and 840 fitted.
25(7).77	672.20	Clutch Ser. No. WAC 532 removed - worn. Clutch Ser. No. 42 Installed.
13.6.77	678.50	Accident occurred.

25. Servicing

a. XX 415 (No 4) A documentation check revealed no discrepancies all servicing was in date and the aircraft had been certified fit for flight by authorised personnel. There was some history of 'vertical bounce' i.e. short term longitudinal instability, and rotor disc vibration in flight during the last 17 flying hours. It is considered that the brinelling of the forward servo input lever lower pivot bolt could have caused instability of the servo jack thus producing vertical bounce.

b. XW 859 (No 6) No significant discrepancies in the servicing or documentation was found. There was no history of long term defects.

AIRCREW SURVIVABILITY AND AIRCRAFT CRASH WORTHINESS

26. The accident was non-survivable. All three aircrew were killed instantly as a result of the impact with the sea. The failure of the pilot seat attachment in XX 415 and the severe damage to the left hand seat of XW 859 was entirely consistent with the high deceleration forces to which the structure of each aircraft was subjected on impact.

DISCUSSION

27. As stated in paragraph 14, the evidence exhibited by both aircraft indicates in flight contact between the two aircraft. The light strike marks on the starboard side of XX 415 appear entirely consistent with contact by the tips of undamaged rotor blades and was almost certainly the initial contact point. The sequence of strikes was most probably upwards and it was noted that the angle of the strikes was such that the main rotor blades of XW 859 would have eventually contacted the underside of the main rotor blades of XX 415. This would appear to be confirmed by the series of rapid bangs heard by the remainder of the formation and the early release of the main rotor blade anti-node balance weight which entered the cockpit of XX 391. This initial contact would appear to have been followed very rapidly by a second contact between the base of the fin of XW 859 and the starboard side of the rear fuselage of XX 415, thus causing the early break up of the rear fuselage. At some stage during this sequence the port side centre section of XW 859 was struck by an object which produced irregular impact marks, most probably a flailing blade from XX 415.

28. The majority of the external witnesses were of the opinion that XW 859 'fell on' XX 415 and then carried on past him into the sea, the wreckage of XW 859 was found approximately 30 metres from XX 415. After the impact with XW 859 the main rotor blades of XX 415 appear to have been so severely damaged that they were no longer capable of supporting the aircraft, the failure of all three flapping/coning stops probably occurring during the near vertical descent to the sea as described by witnesses. The damage incurred to the main rotor blades of XW 859 was considered sufficient to cause loss of control. None of the evidence as seen gave any indication of which aircraft actually moved out of position sufficiently to come into contact with the other. The pilot of XW 856, who had been formating on XX 415 reported that he was not aware of it moving out of its position in the formation. Because of this and the statements of the external witnesses the balance of probability seems to lie with XW 859 moving toward and overtaking XX 415.

29. The severity of the secondary damage to both aircraft, together with the salt water immersion immediately after the accident precluded the full range of rig testing on SAS equipment and hydraulic servo jacks. However, detailed strip examination of the systems of both aircraft failed to reveal any evidence of pre-impact malfunction. The brinelling of the pilot's input lever lower pivot on the forward servo jack of XX 415 would almost certainly account for the history of vertical bounce which this aircraft suffered occasionally in the 17 hours flying prior to this accident. It was not considered relevant to the accident but was considered worthy of investigation by the manufacturers (MOD FORM 760 Ser. No. AIU/144/77 refers). The early stages of brinelling were also noted on all three lower pivot bolts of the servo jacks on XW 859, this aircraft having completed a further 188 airframe hours.

CONCLUSIONS

30. It is concluded that during a formation flying practice of the 'Sharks' Formation Team, aircraft serial Nos XX 415 and XW 859 came into contact and suffered damage which rendered both aircraft uncontrollable and incapable of further flight. No evidence of pre-accident malfunction could be found in either aircraft.

RECOMMENDATIONS

31. There are no technical recommendations rising from this investigation.

[redacted]

Lieutenant RN
Investigating Officer

DISPOSITION OF AIRCRAFT

FIG. 1

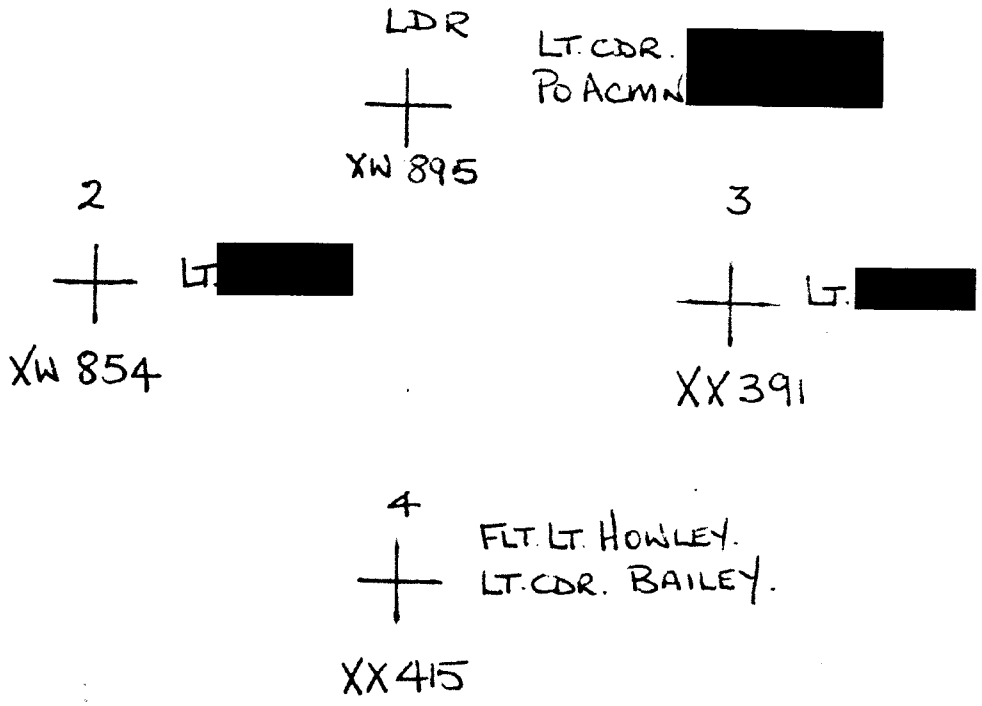

PHOTO 1 Condition of aircraft on salvage

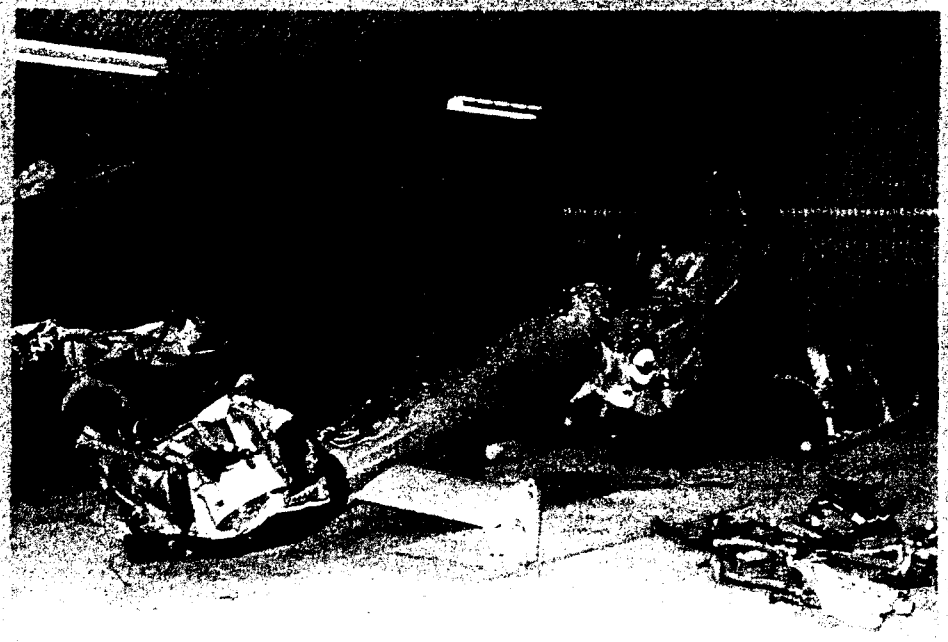

PHOTO 2 XX 415 (No 4)

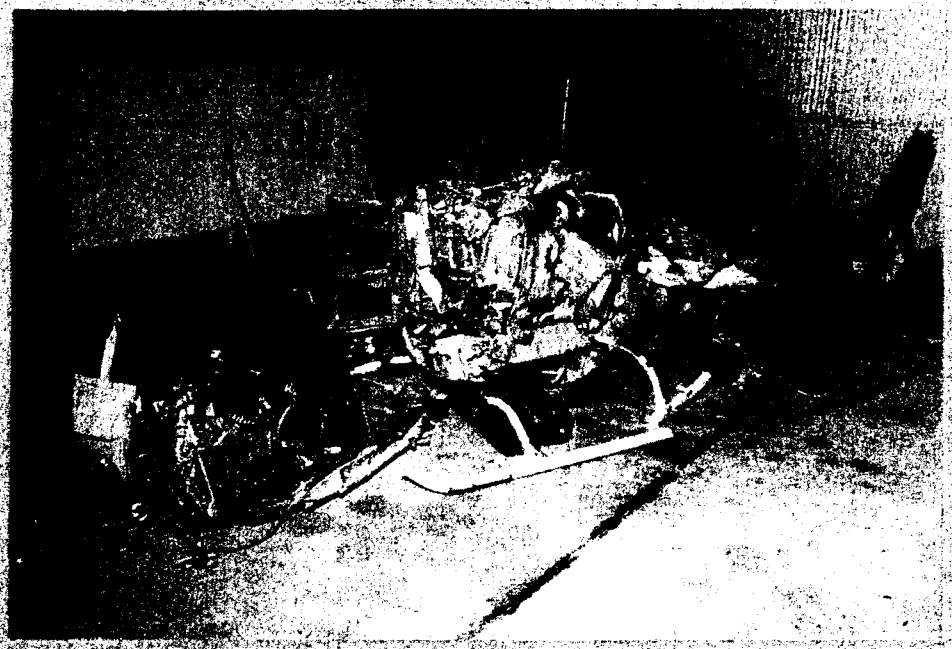

PHOTO 3 XW 859 (No 6)

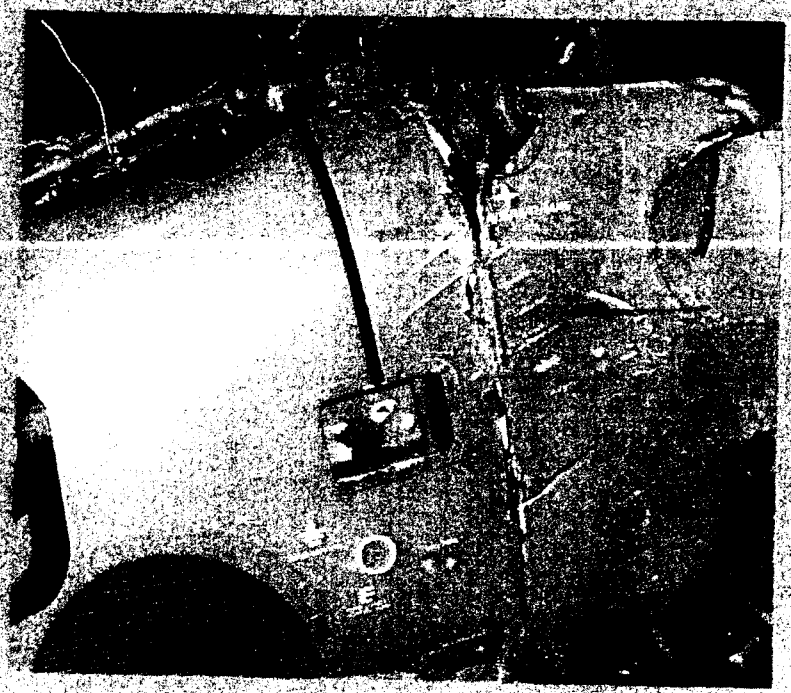

PHOTO 4 Rotor blade strikes

PHOTO 5 Black marks in damaged area of rear fuselage RF 415 (No 4)

PHOTO 6 Comparison of black marks with material from base of fin

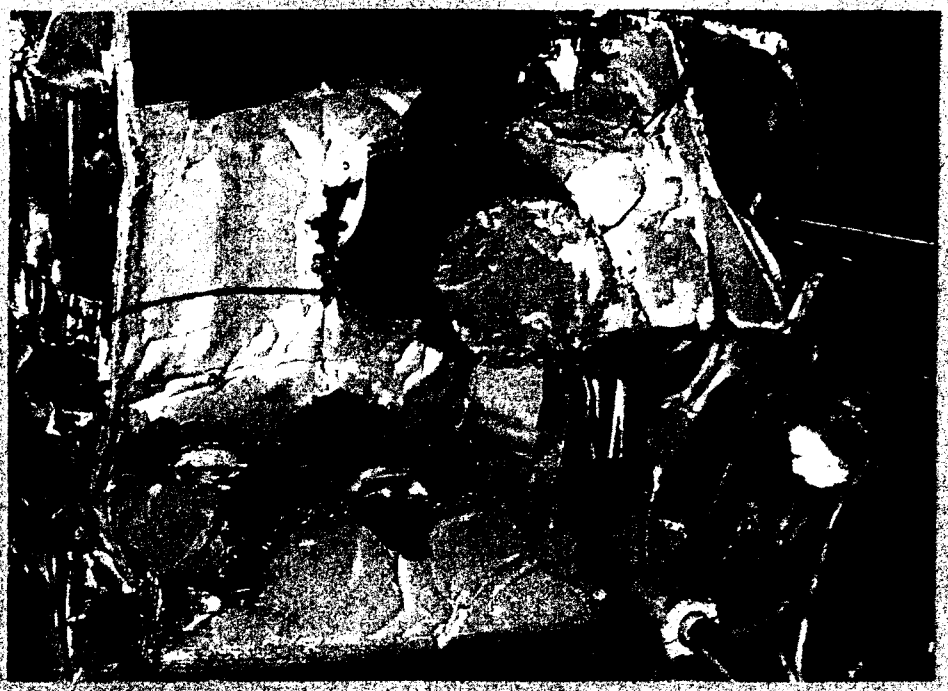

PHOTO 7 Irregular impact marks on remains of left panel centre section XW 859 (No.6)

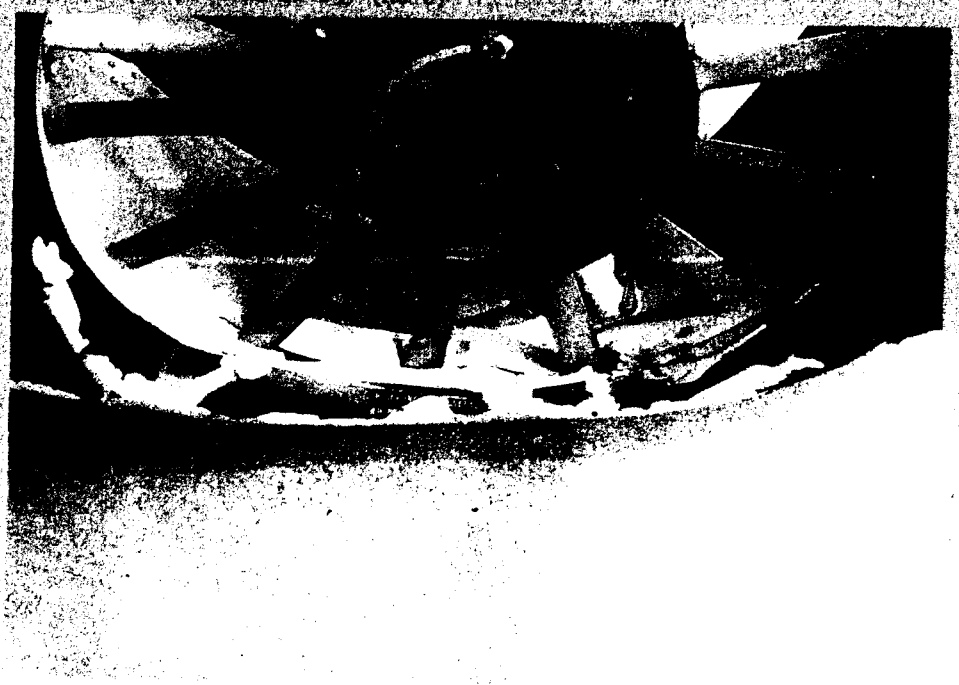

PHOTO 8 Damage to Fenestron of XW 859