No: 2/91	Ref: EW/C1176	Category: 2c

Aircraft Type and Registration:	Hughes 369 HS, G-OAIM
No & Type of Engines:	1 Allison 250-C20 free turbine engine
Year of Manufacture:	1975
Date and Time (UTC):	31 August 1990 at 0956 hrs
Location:	Felsted, Essex
Type of flight:	Private(Business)
Persons on Board:	Crew - 1 Passengers - None
Injuries:	Crew - 1(Fatal) Passengers - N/A
Nature of Damage:	Helicopter destroyed
Commander's Licence:	Private Pilot's Licence(Rotary Wing)
Commander's Age:	75 years
Commander's Total Flying Experience:	2245 hrs(at least 1300hrs on type)
Information Source:	AAIB Field Investigation

History of the flight

The helicopter was based at Graunt Courts, Raynes, Essex. It was refuelled after flight on Tuesday 28 August and the tank was topped up, prior to the planned flight to Battersea Heliport, on the morning of Friday 31 August. An aftercast was obtained from the Meteorological Office at Bracknell. It indicated that the surface wind was 200°/10 kt and the temperature 18° C; the visibility was more than 30 km and there was no significant weather.

The helicopter lifted off at about 0955 hrs. The initial climb trajectory appeared slightly shallower than normal, but nothing else unusual was reported. At about 0955:40 hrs, G-OAIM called Stansted Approach on 125.55 MHz and was told to standby. At 0955:42.4 hrs a primary radar return on Debden Radar was recorded, about 1/2 nm to the south-west of Graunt Courts; the first SSR contact was at 0955:48.6 hrs but, as Mode C had not been selected on the helicopter's equipment, no altitude information was available. Analysis of radar contacts recorded between this time and 0956:13.3 hrs indicated a track of about 230°(M) and a ground speed of approximately 90 kt.

At about 0956:14 hrs Stansted Approach recalled G-OAIM. The pilot started to reply but stopped abruptly after about 4 seconds. There was a short pause and he resumed the transmission with "I'm force landing.."; the microphone remained open for about 9 seconds. The last recorded SSR contact was at 0956:32.1 hrs. The aircraft crashed into a field of stubble on the outskirts of the village of Felsted.

On-site examination of wreckage

The aircraft impacted the ground on a heading of approximately 140° magnetic, banked significantly to the left, with a very high rate of descent and little forward speed. The point of impact was approximately 2 rotor diameters (14 metres) away from a set of power cables, carried on wooden poles, which converged with the aircraft impact heading at an angle of approximately 30° on the right side.

The impact was very severe and resulted in break up of the skids and support structure on the left side, disruption of the left side of the hull and fuel tank, and distortion of the cabin decking structure. The helicopter had then cartwheeled through approximately 270°, coming to rest on its left side approximately 7 metres ahead of the impact point. There was no fire. The pilot, who was wearing a full harness, was killed in the impact.

Four evenly spaced main rotor blade ground strikes were evident along an arc-shaped locus centred approximately on the initial impact point. A small indentation in the ground was also identified, consistent with a tail fin and tail rotor strike.

Three of the main rotor blades had remained attached to the rotor head. The fourth blade had separated during the impact and was lying slightly ahead of the impact point, adjacent to one of the power cable support poles.

None of the main rotor blades displayed significant leading edge damage, suggesting that there had been little energy in the main rotors at the time of impact. All four blades displayed marked upwards curvature and/or localised bending consistent with extensive blade coning caused by very low rotor RPM prior to impact. The tail rotor was relatively undamaged but one blade had been bent and exhibited a deep imprint in the leading edge, probably produced by a stone embedded in the soil. The tail rotor drive shaft had fractured as a result torsional overload, consistent with a tail rotor groundstrike during the impact.

An external examination of the engine at the accident site did not reveal any evidence of abnormality in those areas of the engine which were accessible. Similarly, no evidence of abnormality was found in the accessible areas of the main rotor, the rotor head, or transmission, except for damage directly attributable to the impact and to the effects of very low main rotor RPM.

Because of the total disruption of the fuel tank and fuel feed pipelines during the impact, it was not possible to obtain fuel samples from the aircraft. However, a sample of fuel was taken from the bulk supply from which the aircraft had been refuelled. Analysis of this sample confirmed that the aircraft had been fuelled with clean JetA1 fuel. Witnesses who arrived on the scene immediately after the accident confirmed that large quantities of fuel had been released at the impact point, and the interior of the cabin and furnishings remained fuel soaked for some considerable time after the event.

When the cockpit was examined on-site, the *engine-out* circuit breaker was found to be *out;* there was no evidence to suggest that it had *popped* as a result of the impact. This circuit breaker controls both the aural and visual engine-out warning systems. No other discrepancies were noted in the cockpit. The auto re-ignition switch was set to *off.*

Detailed technical investigation

The aircraft wreckage was recovered to the AAIB wreckage examination facility at Farnborough, where it was examined in detail. A copy of the ATC tape containing the two short periods of transmission from G-OAM was subjected to spectral analysis for evidence of rotor transmission (ie gearbox) and/or engine frequencies (ie speeds) in the background noise. A copy of a segment of ATC tape containing a transmission from G-OAIM made during the departure phase of the preceding flight, carried out three days previously, was also analysed in order to obtain a 'control sample' against which the analysis of the accident flight main rotor transmission frequencies could be judged.

From the spectral analysis it was possible to identify frequencies which it is believed were consistent with the rotational speed of the main transmission input shaft, though a measure of uncertainty existed regarding the exact value of rotor RPM (%Nr) because of possible variations in the speeds of the recorder tape transport mechanism. The analysis nevertheless provided valuable indications of rotor RPM trends during the three periods of ATC transmission made during accident flight, together with approximate values of rotor RPM. In fig1 the variation in rotor RPM, expressed as percentage Nr, is plotted against an arbitrary time base in seconds, together with speech transcripts. The nominal value of main rotor RPM during the initial transmission, when there was apparently no problem, was steady at a (nominal) value of about 104% (data uncorrected for tape transport errors). However, at the start of the second transimission, RPM is decaying rapidly from an initial value of approximately 109% Nr to a value of approximately 96% at the time that this transmission terminates some 2-3 seconds later. When the transmission resumes, some 4 seconds later, RPM has decayed to approximately 70% Nr, and thereafter appears to stabilise for about 9 seconds at values between 66% Nr and 70% Nr, before falling rapidly to about 56% immediately prior to the end of the transmission.

The indications of very low rotor RPM were consistent with both the heavy blade coning observed on all main rotor blades and with the very high rate of descent at impact, and clearly indicated that the main rotors were not being driven under significant power at any time during the descent.

Examination of the airframe, flying controls, rotor systems and main transmission revealed no evidence of any pre-impact failure or malfunction. There was no evidence that any of the cockpit warning captions were illuminated at impact. The low rotor RPM warning horn was tested and found to operate satisfactorily. However, both the warning horn and the *engine out* warning caption would have been disabled by the pulled *engine out* circuit breaker.

No warning horn could be heard on the recordings of the ATC transmissions.

Engine examination

An external examination of the engine prior to removal from the airframe confirmed that both the gas producer and power turbine rotating assemblies were free and that the main transmission and over-run clutch were intact. However, it was found that the nut (of a type known as a "B" nut) securing the compressor delivery pressure sensing (PC) pipe to the elbow fitting at the compressor discharge casing was undone and the pipe had separated from the elbow.

No evidence was found to suggest that the nut had come undone, or had been knocked off, during the impact, although the pipe had suffered some impact damage at its opposite end, where it attaches to the power turbine governor (PTG). All the evidence clearly indicated that the nut had come undone prior to the impact, and the impact damage to the pipe at its aft end, adjacent to the PTG, had merely resulted in the already disconnected pipe moving further from the elbow at its forward end.

Dimensional checks on the nut and the elbow fitting showed that both the male and female thread forms were within limits, for all practical purposes, and that the nut and elbow assembly was fully capable of being tightened to the torque loading specified in the maintenance manual.

The PC pipe supplies both the power turbine fuel governor and the gas producer fuel control unit with a reference pressure which is used by both systems as an indication of gas producer speed. Any reduction in PC pressure, as seen by the fuel control/governor units, would result in a reduction in fuel flow. A major leak in the PC air pipework, due to a complete disconnection of the pipe, would cause the engine to run down to idle; intermediate conditions involving a partial leak would potentially produce power reductions of lesser proportions. Variations in leakage rate caused by movement of a loose pipe connection might be expected to produced power fluctuations, though the magnitude of such fluctuations cannot be accurately predicted.

The engine was removed from the airframe and strip examined under AAIB supervision by an approved overhaul agency. All pipe connections were checked for correct torque values and found to be satisfactory with the exception of a small number of nuts which had suffered impact disturbance, and which were found to have been loosened very slightly as a consequence. All fuel controls, governors, pumps and related items of equipment were tested against the manufacturer's specifications and found to operate satisfactorily. The fuel nozzle functioned satisfactorily with the exception of a higher than normal flow rate. However, the spray pattern of the nozzle was good and the high flow rate was well within the compensating range of the fuel control system. Disassembly of the main rotating assemblies and combustion chamber revealed no evidence of pre-impact defects which could affect engine performance.

Maintenance history

The aircraft had been inspected for the renewal of its certificate of airworthiness (C of A) on 21 August 1990, some 10 days prior to the accident. It had subsequently flown a total of 3:40 hours up until the time of the accident, based upon estimated flight times.

As a part of the maintenance work associated with the C of A renewal, the engine had been removed for the replacement of a turbine wheel which was approaching the end of its service life.

With the engine on the workbench, the turbine module was removed. This involved the removal of the PC pipe from the 'tee' piece adaptor at the PTG, to permit removal of the PTG and the fuel control unit (FCU) in preparation for the separation of the turbine module. It would not have been essential to slacken or remove the PC pipe at its forward end in order to remove the PTG.

The axial compressor was inspected for liner condition and for corrosion induced fatigue cracking of the compressor blades, with access being gained by the removal of each compressor half-case section in turn, the manner usually adopted for the inspection of Allison 250 series compressors. This necessitated removal of the compressor de-icer pipework and other sundry items to allow removal of the half-cases, but there was no requirement to remove the PC pipe. After completion of the compressor inspection, the forward section of the engine was re-assembled and inspected.

The turbine section had been sent away for repair by a specialist repair agency and, because it was found that a second turbine wheel also required replacement, it became apparent that there would be a delay before the turbine module was returned. In order to expedite completion of work on the aircraft, the forward section of the engine was installed in the airframe with a view to installing the turbine module later, when it was returned by the repair agency. Upon its return, it was assembled on to the main engine casing, in the airframe, and the PTG, FCU and associated components and pipework replaced, checked and marked with torque indicator paint.

It has not been possible to establish positively at what stage the PC pipe forward connection was made, or indeed if the connection was ever loosened at any stage during the re-build. With the exception of the disconnected "B" nut at the forward end of the PC pipe, all "B" nuts associated with the PTG, FCU, fuel pump, filter and related system components were marked with a bright orange/brown torque paint, which was of fresh appearance and had clearly been recently applied. In contrast, the torque paint on the disconnected nut was a dark brown colour and had clearly been applied at some considerable time in the past. A very small blob of the fresh orange torque paint was evident on the tip of the locking wire securing the elbow fitting to the compressor discharge case, but no *fresh* paint was evident on the nut, the pipe, the pipe collar, or the elbow fitting itself. With the engine installed in the airframe, the forward fitting of the PC pipe is relatively difficult to access compared with the aft end of the pipe.

None of the "B" nuts used to secure system pipework on the Allison engine is wire locked; locking is achieved solely by correct torque tightening of the nut to values specified in the maintenance manual. The manufacturer states that this method of locking is satisfactory provided that the nuts are correctly tightened.

A review of international accident and incident data covering the Allison 250 series engines since 1976 has highlighted a total of 26 accidents attributed to air leakage from the PC air signal system, 12 of which involved loose pipe nuts or fittings. The records during this same period attribute 3 accidents to loose "B" nuts on fuel system pipework.

The CAA have been recommended to review the work practices generally in use by maintenance organizations engaged in the disassembly and rebuilding of modular engines.

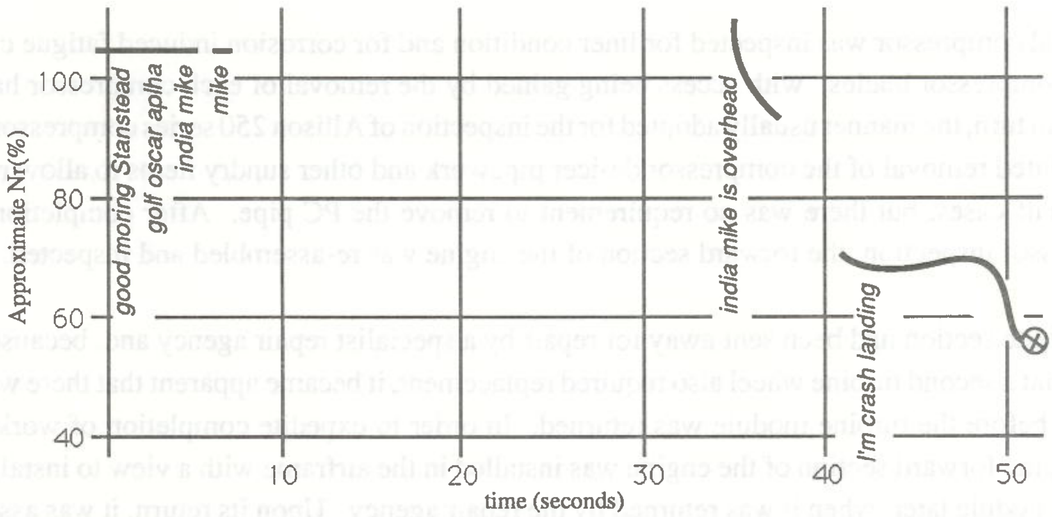

Fig 1. G-OAIM Hughes 369 Helicopter
Main rotor RPM trends derived from ATC recording
(transmissions from G-OAIM in italics)

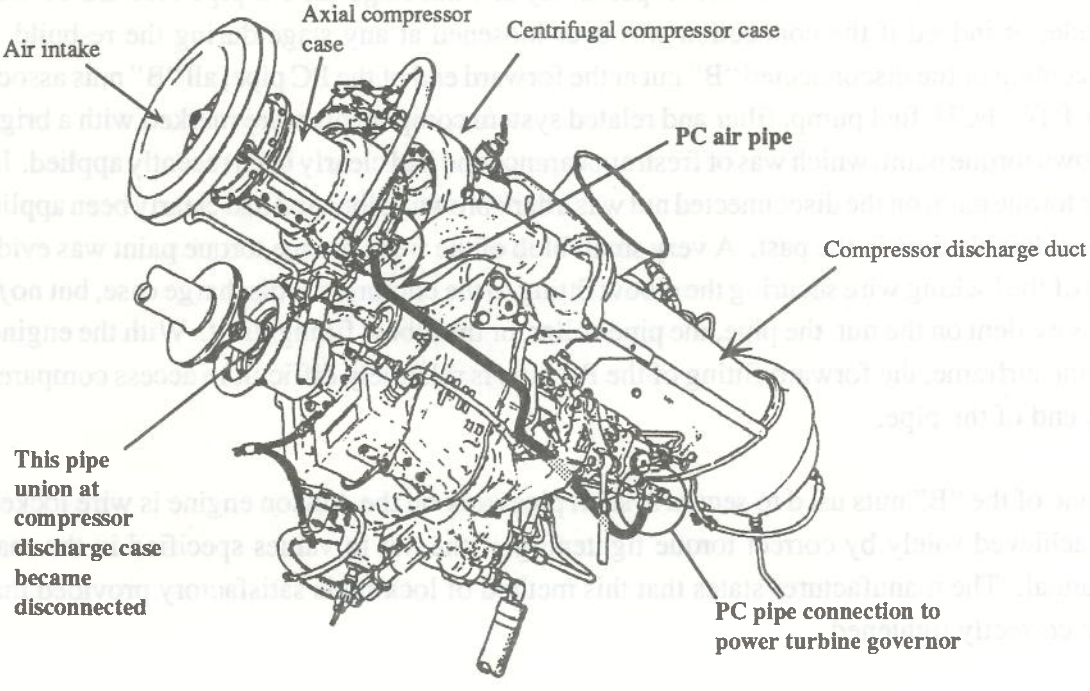

Fig 2. Allison C250 engine
(location of PC air pipe)

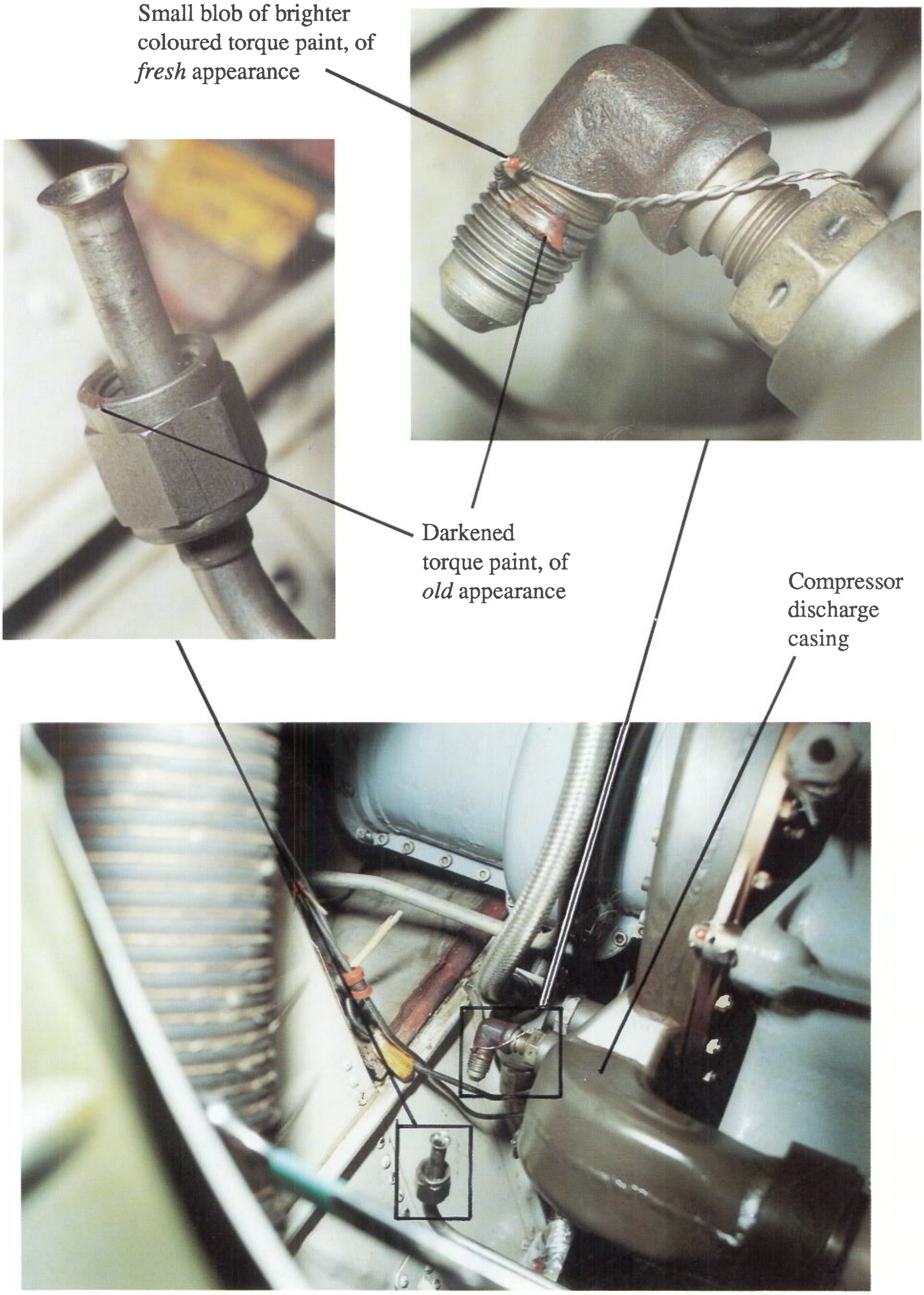

Fig. 3 PC air pipe at compressor casing on G-OAIM
(shown disconnected, *as found* post accident)