ACCIDENTS INVESTIGATION BRANCH
Department of Trade and Industry

BOAC Vickers Super VC 10 G-ASGK Report on the accident near Reading, Berkshire on 27 November 1969

LONDON: HER MAJESTY'S STATIONERY OFFICE
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Department of Trade and Industry
Accidents Investigation Branch
Shell Mex House
Strand
London

24 March 1971

The Rt. Honourable John Davies MP
Secretary of State for Trade and Industry

Sir,

I have the honour to submit the report by Mr R C Warren, an Inspector of Accidents, on the circumstances of the accident to Vickers Super VC 10 G–ASGK which occurred during flight, near Reading, Berks on 27 November 1969.

I have the honour to be

Sir,

Your obedient Servant,

V A M HUNT
Chief Inspector of Accidents

Accidents Investigation Branch

Civil Accident Report No. EW/C331/01

Aircraft:	Vickers Super VC 10 G–ASGK		
Engines:	Four Rolls Royce Conway 550		
Owner and Operator:	British Overseas Airways Corporation		
Crew:	Commander	– Captain J H Smurthwaite	uninjured
	Co-Pilot	– Second Officer A K Smee	uninjured
	Navigator	– Second Officer R A Small	uninjured
	Flight Engineer	– Senior Engineering Officer R Frobisher	uninjured
	Senior First Officer	– Senior First Officer G A Reed	uninjured
	Senior Steward	– Mr A Hitchman	uninjured
	Steward	– Mr J M Richardson	uninjured
	Steward	– Mr M Pearce	uninjured
	Stewardess	– Miss O Hammond	uninjured
	Stewardess	– Miss F Gordon-Smith	uninjured
	Stewardess	– Miss A W Roberts	uninjured
Passengers:	58		uninjured
Place of Accident:	During flight, near Reading, Berks.		
Date and Time:	27 November 1969 at approximately 1020 hrs.		
	All times in this report are GMT		

Summary

During the en route climb following a normal departure from London (Heathrow) Airport, a failure occurred in No 3 engine which caused the complete detachment of the thrust reverser, exhaust cone assembly and cowling. Fragments from No 3 engine caused damage to No 4 engine which then caught fire. Both engines were shut down and the fire went out. The aircraft returned to its point of departure and made a successful overweight landing.

None of the 58 passengers or 11 crew was injured. No injuries were caused to persons on the ground although the engine parts which fell away from the aircraft in flight caused damage to property in the Reading area.

The sequence of failure of No 3 engine started with the shedding of blades from the 2nd stage low pressure turbine wheel during the take-off phase.

1. Investigation

1.1 History of the flight

The aircraft took off from London (Heathrow) Airport (LHR) at 1015 hrs on a scheduled service to New York. During the take-off run, passengers and cabin crew seated in the rear of the aircraft heard an unusual rubbing noise and thought that the take-off was being abandoned. However, no abnormal indications were noticed by the crew on the flight deck. The normal noise abatement procedure was followed during the departure and at 3,000 feet climb power of 94 per cent rev/min was restored and the 'after take-off' checks were carried out. At this time the Senior Steward reported the unusual noise heard during take-off to Senior,First Officer Reed but as all conditions appeared to be normal, no action was taken.

During the initial climb the attention of an eyewitness on the ground was drawn to the aircraft by a rattling noise emanating from the engines as it passed over Egham.

Shortly before reaching Woodley MF beacon a layer of cloud was encountered at 5,000 feet and engine anti-ice was selected. At 1020 hrs the crew heard a loud bang which was followed almost immediately by a fire warning indication on No 4 engine. Coincident with the commander issuing an order for fire action on No 4 engine, the flight engineer reported that No 3 engine was running down and could not be relit. As it appeared possible that this was the primary failure and that the fire warning for No 4 engine could have been false, the commander decided that No 3 engine should be shut down first and he ordered the appropriate action to be carried out. Whilst this was being done, the No 3 engine fire warning light came on and fire action was therefore ordered by the commander. According to Second Officer Smee's statement this included the operation of the fire handle to discharge the extinguisher. Shortly after this action was taken, No 3 fire warning light went out. The fire warning light for No 4 engine was still on at this stage, and the commander therefore ordered fire action to be carried out on that engine. Whilst this was being done, the fire warning light went out when the fire handle was pulled, and it was decided, therefore, not to operate the extinguisher but to keep it in reserve in case of a recurrence of fire in either engine.

At about this time an eyewitness on the ground at Reading saw part of the aircraft fall through the clouds. This was subsequently found and identified as the rear part of No 3 engine.

When the emergency occurred Second Officer Smee, who was sitting in the right hand seat acting as co-pilot, advised London Radar of the situation and, on the commander's instructions, requested an immediate return to LHR. The aircraft was instructed to turn right on to a heading of 060° and was then vectored back to the airport. The commander decided that as there had

been a serious engine fire and an unknown amount of structural damage it was inadvisable to jettison fuel even though his decision would involve landing 38,877 kgs over the normal maximum permitted landing weight. This necessitated a final approach and touchdown speed of 168 knots, which was about 25 knots faster than normal. The commander also decided that Senior First Officer Reed should take Second Officer Smee's place in the right hand seat. As Nos 3 and 4 engines had been shut down, no hydraulic supply pressure was available in the 'B' hydraulic system and the starboard main gear had therefore to be lowered by the emergency free fall method. (NB The port main gear and nose gear are operated by the 'A' hydraulic system and could therefore be lowered normally).

As the 'B' system hydraulic accumulator was fully charged there was sufficient pressure to bring the aircraft to a stop with the anti-skid braking system in association with full reverse thrust on Nos 1 and 2 engines. After stopping, the aircraft was moved clear of the runway and a full normal shut down procedure was carried out. Three of the starboard main wheel tyres deflated when the fusible plugs operated due to high temperature generated by brake friction. The forward escape slides were kept in readiness in case emergency evacuation was necessary but they were not required as the passengers and crew left the aircraft by means of steps brought from the central area.

1.2 Injuries to persons

Injuries	*Crew*	*Passengers*	*Others*
Fatal	–	–	–
Non-fatal	–	–	–
None	11	58	

1.3 Damage to aircraft

No 3 engine and its associated structure sustained serious damage. No 4 engine was damaged by flying debris from No 3 engine and by fire. Flying engine debris also made a small hole in the rear fuselage, penetrating the pressure hull.

1.4 Other damage

A small amount of damage was caused to a factory roof at Reading by debris falling from the aircraft. No other damage has been reported.

1.5 Crew information

Captain J H Smurthwaite, aged 47, held a valid airline transport pilot's licence endorsed for command of VC 10 aircraft. He had flown a total of 13,562 hours of which 2,211 hours had been in command of VC 10 aircraft. His certificate of competency was valid until 23 March 1970 and his medical validity extended to 22 January 1970. During the 30 days preceding the accident he had flown a total of 64 hours, all on VC 10 aircraft. His rest period immediately prior to this flight was 83 hours.

Senior First Officer G A Reed, aged 40, held a valid airline transport pilot's licence endorsed in Part 1 for VC 10 aircraft. He had flown a total of 9,861 hours of which 2,858 hours had been on VC 10 aircraft. His certificate of competency was valid until 27 February 1970 and his medical validity extended to 23 January 1970. During the 30 days preceding the accident he had flown a total of 63 hours all on VC 10 aircraft. His rest period immediately prior to this flight was 75 hours.

Second Officer A K Smee, aged 21, held a valid commercial pilot's licence endorsed in Part 2 for VC 10 aircraft. He had flown a total of 984 hours of which 417 hours had been on VC10 aircraft. His certificate of competency was valid until March 1970 and his medical validity extended to 25 March 1970. During the 30 days preceding the accident he had flown a total of 44 hours all on VC 10 aircraft. His rest period immediately prior to this flight was 121 hours.

Second Officer R A Small, aged 24, was acting as navigating officer on this flight. He held a valid commercial pilot's licence endorsed in Part 2 for the VC 10 aircraft.

Senior Engineer Officer R Frobisher, aged 41, held a valid flight engineer's licence endorsed for VC 10 aircraft. He had flown a total of 6,222 hours of which 2,903 hours had been on VC 10 aircraft. His medical validity extended to 24 September 1970. During the 30 days preceding the accident he had flown a total of 56 hours all on VC 10 aircraft. His rest period immediately prior to this flight was 11 days.

1.6 Aircraft history

G–ASGK was constructed in 1967 and went into service with BOAC the same year. It had been regularly serviced in accordance with an approved maintenance schedule and, at the time of the accident, its certificates of maintenance and airworthiness were valid. It was last inspected on 3 November 1969 and had flown a total of 6,527 hours since construction. No 3 engine was completely overhauled by BOAC engine overhaul base at Treforest on 30 May 1969 and it was installed in G–ASGK on 1 July 1969. At the time of the accident it had run 1,636 hours since this overhaul. The life between complete overhauls is normally 6,000 hours. The day before the accident the oil filters were examined during routine inspection and found to be satisfactory. An ultrasonic crack detection check was carried out on No 3 engine LP 2 turbine blades on 30 October 1969, and was reported as satisfactory. However, evidence obtained from the flight recorder indicates that the performance of No 3 engine had deteriorated over a period prior to the accident, (see section 1.11).

1.7 Meteorological information

An appreciation of the weather conditions at the time in the LHR/Reading area gave a freezing level of approximately 3,250 feet, small amounts of cumulus cloud with a base of 2,000 feet and 5/8 to 7/8 stratocumulus base 3,000 to 6,000 feet. The height of the tops of all low cloud was near 6,000 feet. A sharp inversion existed between 6,000 and 6,500 feet and the temperature just below the inversion was $-5^{\circ}C$ to $-6^{\circ}C$. It is likely that turbulence occurred beneath this inversion.

With the given temperature and the possibility of turbulence there could have been moderate icing in the cloud above the freezing level. A horizontal visibility of 8–15 kilometres was reported in the area and the surface was given as 260° 06 knots. The incident occurred in daylight.

1.8 Aids to navigation

The aircraft was making a 'Brecon One' standard instrument departure from LHR. The emergency occurred immediately after passing over the Woodley MF beacon and the aircraft was vectored back to the ILS on Runway 28R at LHR by radar.

1.9 Communications

Normal VHF communications were established and maintained on the appropriate control frequencies.

1.10 Aerodrome and ground facilities

Fire fighting and rescue appliances were alerted and available at the aircraft immediately it came to a standstill. After the fire officer in charge had conferred with the commander, the fire service stood by at the aircraft until the wheels and brake assemblies had cooled.

1.11 Flight recorder

The aircraft was equipped with an Epsylon Flight Data Acquisition System consisting of two recorders. The first of these, which was mounted adjacent to the aft face of the transverse engine beam, records the mandatory flight path parameters, namely: pressure altitude, indicated airspeed, magnetic heading, pitch attitude and normal acceleration. The second, which was installed in the under floor electronics bay, records a considerable amount of additional information for domestic purposes, including the following relevant parameters:

(i) Engine low pressure compressor (NI) rpm.
(ii) Engine fire warning.
(iii) Engine failure warning.

In the case of the first recorder, significant signal 'drop out' occurred during the flight, being particularly severe during the take-off phase and again just prior to the failure of No 3 engine. It was deduced that the signal 'drop out' was the result of the wire leaving the recording head due to abnormal vibration being applied to the wire cassette of this recorder through the adjacent main transverse engine beam.

Usually NI rpm indications for each of the four engines are available on the second recorder but it was found on replay that the signals from No 2 engine had failed to record. Comparison of the percentage NI rpm values of the three engines, (Nos 1, 3 and 4) for which recordings are available show that the rpm of No 3 engine were significantly less than the other three engines for the whole period of the flight up to the time of failure. Deterioration of the performance of No 3 engine was also indicated when NI rpm recorded on previous flights was played back. This covered 13 sectors

between 4 and 9 September, 8 sectors between 11 and 14 November and 22 sectors between 21 November and the subject flight. The recordings for the intervening periods were not available.

The engine fire warning circuit for the flight recorder was connected in parallel to the engine fire audible warning circuit and a fire warning event would therefore be recorded on every occasion on which a detector on any engine caused the audible warning to operate.

The engine failure circuit for the flight recorder was connected in parallel to the engine failure lights. An engine failure event would, therefore, be recorded and the engine identified whenever an overheat or low oil pressure condition was sensed for a particular engine.

On the subject flight an engine failure warning event for No 3 engine was recorded at about 1020 hrs. An engine fire warning occurred at about the same time and this was followed by an engine failure event for No 4 engine about 20 seconds later. No fire warning event for No 3 engine was recorded, as by the time it occurred, the audible warning circuit had been isolated by the crew.

1.12 The aircraft

1.12.1 Inspection of the aircraft

A small hole had been punctured in the rear fuselage adjacent to No 3 engine by a piece of metal ejected from the failed turbine. There was no fire damage to the fuselage or passenger cabin. The fire extinguisher bottles for Nos 3 and 4 engines had not been discharged.

There was extensive mechanical damage to the LP 2 turbine section of No 3 engine. The by-pass duct was split open axially and had been torn right round in a ragged fracture just aft of the thickened section which surrounds the LP turbine. The whole of the exhaust unit and thrust reverser assembly had seperated from the engine and was missing. No 4 engine had been slightly damaged by fire. After inspection both engines were removed from the aircraft for further examination.

1.12.2 No 3 engine wreckage distribution

The thrust reverser and exhaust unit assembly from No 3 engine was recovered from a field in the Reading area west of the Woodley beacon. A subsequent search of the area in the vicinity produced pieces of nacelle cowling and engine by-pass ducting, oil feed piping and clips, turbine blades and stator blades, the LP turbine rear bearing support housing, its outer race and a piece of the bearing cage. All these pieces were found in an area of about one mile square, below the position where it was estimated the loud bang occurred in the air. Two pieces of by-pass ducting were also recovered from a position six miles north of the main wreckage area. It is considered that these pieces had remained loosely attached to the remainder of the engine after the thrust reverser assembly had broken away and had subsequently become detached due to flapping in the turbulent airflow. No further parts have been recovered.'

1.12.3 Strip examination of Nos 3 and 4 engines

A detailed examination of No 3 engine in collaboration with the manufacturers showed that there were a number of parts still missing. These included 37 out of the 67 LP 2 turbine blades, all the rollers and most of the cage from the LP turbine bearing, the bearing heat shield, front oil seal and end plate. The LP turbine bearing inner track was in place on the shaft but was deeply scored. The LP 1 turbine rotating assembly was complete with all blades, the trailing edges of which had impact damage of varying degrees. All but one of the LP 2 turbine blades had been torn out of the turbine disc. The disc itself, which was intact, showed evidence of overheating on its rear face which was consistent with an oil fire, intense and localised, emanating from the failed turbine bearing. There were indications on the inner race of this bearing of out of balance running. An inspection of the LP and HP compressors showed them to be all intact and the bearings adequately lubricated. There was some slight evidence of blade tip rubbing and inter-blade touching consistent with surging and out of balance running but this is considered to be secondary to the LP 2 turbine failure. One of the light alloy engine mountings on the LP compressor casing had fractured but this was probably also secondary to the turbine failure. There was no evidence of any form of ingestion in the compressors. The magnetic chip detectors and filters were contaminated with ferrous and bronze particles respectively.

Examination of No 4 engine revealed that it had sustained a certain amount of damage adjacent to the inter-engine fire wall where it had been penetrated by debris from the LP 2 turbine of No 3 engine. The by-pass duct had been holed and the oil feed pipe to the rear bearing had been fractured. Apart from this damage No 4 engine was intact.

1.13 Fire

1.13.1 The fire in the air

The fire in No 4 engine bay, which caused only minor damage to the rear cowlings, was a secondary effect following the mechanical disruption of No 3 engine LP 2 turbine blades. The fractured oil pipe connection leading to the rear turbine bearing of No 4 engine resulted in the release of oil under pressure which was ignited immediately either by flames from the severed turbine section of No 3 engine or spontaneously from the hot turbine casing; the fire detection wire in the vicinity signalled the fire warning to the flight deck.

1.13.2 The fire extinguisher system

The fire extinguisher system and its flight deck controls were examined immediately after the accident. This showed that both No 3 and No 4 fire control handles on the flight deck had been pulled out and were in a horizontal position. The high pressure fuel cocks for both No 3 and No 4 engines were in the 'OFF' position. The low pressure fuel cocks and their switches were in the 'OFF' position and the hydraulic oil shut off cocks and switches were also 'OFF'. The 'extinguisher bottle fired' indicator bulbs were clear indicating bottle not discharged. These bulbs should fuse to permanent red colour whenever the fire control handle is turned sufficiently to discharge a fire bottle. Electrical continuity and insulation tests proved the

circuit to be satisfactory from the flight deck switches to the extinguisher bottles. The firing heads and the connections to the bottles were intact and not damaged by fire. A test to discharge the fire extinguisher was then carried out using No 3 fire control handle on the flight deck. Since this handle was already pulled out, it was turned clockwise to the limit of its travel (30^{o}) to fire the first shot as a result of which No 3 bottle discharged satisfactorily and its indicator bulb fused to red. It was found that only the last few degrees of rotation of the fire control handle will operate the fire extinguisher as the electrical contact is made at the end of the movement and thus may not operate if the handle is not turned to its full extent.

1.14 **Survival aspects**

Not applicable.

2. Analysis and Conclusions

2.1 Analysis

Due to the fact that a number of engine parts, particularly turbine blades, were not found it has not been possible to determine with certainty the cause of the failure of No 3 engine. The degree of unbalance which must have existed in the engine at an early stage in the flight suggests that the most probable cause was a primary failure of one or more adjacent LP 2 turbine blades. An analysis of all the evidence available suggests a probable sequence of events as follows:

(a) During the take-off roll a primary failure occurred in the LP turbine system which resulted in the rotating assembly becoming severely out of balance. (NB High readings on the vibration analyser on the flight deck can normally be expected during take-off, and the company flying manual instructs crews to take no action in such an event until after the first power reduction).

(b) The out of balance running of the rotating assembly caused the bearing at the rear of the LP turbine to fail which in turn led to the failure of the bolts securing the LP turbine bearing heat shield to the bearing support housing.

(c) The loss of radial location due to failure of the LP turbine bearing permitted the LP turbine shaft to orbit about its displaced mass centre and this reduced the extreme vibration caused by the primary failure. The residual vibration level detected by the vibration analyser would probably have appeared normal at this stage.

(d) The continued operation of the engine caused rapid deterioration of the interstage seals between Nos 1 and 2 LP turbines resulting in a partial loss and contamination of the cooling air flow to the LP 2 turbine disc rear face.

(e) Oil, which was by then leaking from the LP turbine bearing, ignited and burned fiercely behind the LP 2 turbine disc.

(f) Gross overheating of the LP 2 turbine disc resulted in loss of material strength which was followed by physical growth of its component parts (particularly the rim of the disc), and in the uncontained release of a number of LP 2 turbine blades through the turbine casing. Interference between the LP 2 blades and nozzle guide vanes resulted in all but one of the LP 2 turbine blades and all the nozzle guide vanes being torn out and ejected through the casing. Damage to the casing caused the exhaust unit and thrust reverser to fall away from the aircraft.

(g) Some portions of the ejected metal debris damaged the inter-engine bulkhead and struck the oil pipe feeding the LP 2 turbine bearing in the adjacent No 4 engine. This impact fractured the cast aluminium elbow connection and released oil at pressure.

(h) Oil from the fractured pipe ignited and caused a minor fire in the rear lower section of No 4 engine bay. The heat from this fire probably activated the fire warning system in No 3 engine. Subsequently the fire in No 4 engine bay went out of its own accord.

It is onf some concern that the disintegration of No 3 engine resulted in substantial pieces of it becoming detached from the aircraft, thus not only hazarding the safety of the flight, but also persons on the ground below. Engine manufacturers and the safety authorities are very conscious of the need to ensure that parts of an engine are contained following a failure and to this end design criteria are laid down by the Air Registration Board. However it is clearly very difficult to apply standards which will ensure that nothing falls from an aircraft in the case of a massive disruption such as took place on this occasion. Nevertheless a number of early warning devices, which will give advance indication of this type of engine failure, are under investigation by the engine manufacturers.

When the emergency first occurred, the crew were faced with a difficult and perplexing sequence of events inasmuch as No 4 engine fire warning light came on at the same time as No 3 engine ran down. As all other indications on No 4 engine were quite normal, it seemed initially to the flight engineer that there was either an electrical fault which was wrongly indicating a fire in No 4 engine instead of No 3, or that No 3 had failed and had affected No 4 in some way so as to cause its fire warning light to come on. In view of the aircraft's weight, it was desirable from the commander's point of view to retain the use of No 4 engine if at all possible and he therefore decided not to proceed for the moment with the fire action which he had initially ordered on that engine, but to deal with the failure of No 3 first. There was always the possibility that this would also have the effect of clearing the fire indication on No 4 engine, assuming it to have been false, thus making it unnecessary to shut that engine down. In the event, the No 4 fire warning light remained on after No 3 engine had been shut down, and the commander was therefore left with no other alternative but to take the appropriate fire action and shut down No 4 engine also.

The incomplete operation of the fire handle during the fire action on No 3 engine, which resulted in the fire extinguisher not being discharged, was not in fact crucial in this case. However revised training procedures have since been introduced by BOAC to ensure that all pilots are aware that the extinguishers will not discharge unless the fire handles, after being pulled, have been turned fully against their stops.

An approach and landing with only two engines operating was well within the performance capabilities of the aircraft, even allowing for the fact that the weight was considerably in excess of the normal authorised maximum for landing. There was no risk of a structural failure involved in landing at above the normal weight as it is an Air Registration Board requirement that landings can safely be made in an emergency at the design take-off weight. The runway length available to the aircraft at London (Heathrow) Airport more than adequately met the landing distance requirements of the aircraft in the prevailing circumstances. The decision of the commander on this occasion not to reduce the weight of the aircraft prior to landing by means of fuel jettisoning was justifiable in the circumstances as he saw them at the

time as he was unsure whether or not the tail and jettison assemblies had been damaged.

2.2 Conclusions

(a) Findings

(i) The aircraft had been maintained in accordance with an approved maintenance schedule and its documentation was in order.

(ii) The crew were properly licensed and adequately experienced for the flight.

(iii) A failure of the No 2 low pressure turbine system of No 3 engine occurred during the take-off phase.

(iv) The resultant vibration brought about the failure of the rear bearing of No 3 engine.

(v) Overheating, due to a consequential internal oil fire, led to turbine disc growth and release of blades which severed the turbine casing causing the exhaust unit and thrust reverser to fall from the aircraft.

(vi) Metal debris from the failed LP 2 turbine penetrated the inter engine fire wall and struck the adjacent No 4 engine fracturing the oil pipe connection to its turbine bearing. Release of oil from this fractured pipe connection ignited and caused minor fire damage to the No 4 engine cowlings.

(vii) Fire action was ordered on both Nos 3 and 4 engines but the evidence indicates that No 3 fire handle after being pulled, was not turned sufficiently to discharge the fire extinguisher.

(b) Cause

The disintegration of No 3 engine most probably stemmed from the failure of one or more turbine blades in the No 2 LP turbine during the take-off phase. The fire which occurred in No 4 engine bay was caused by damage resulting from the disintegration of No 3 engine.

R C WARREN
Inspector of Accidents

Accidents Investigation Branch
Department of Trade and Industry
March 1971

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