

No. 12

Britannia Airways Ltd., Britannia 102, G-ANBB, accident near Ljubljana Airport, Yugoslavia, on 1 September 1966. Report released by the Commission of Inquiry, Yugoslavia, on 6 September 1968

1. - Investigation1.1 History of the flight

Flight BY 105 was a non-scheduled international flight from Luton (England) to Ljubljana (Yugoslavia), for the transport of tourists.

The aircraft took off from Luton at 2110 hours GMT on 31 August 1966, with a crew of 7 and 110 passengers. Before overflying the Yugoslav border, the crew contacted the Zagreb Area Control Centre. The radiocommunications were uninterrupted, and the crew received all necessary information and instructions. After overflying Klagenfurt, the crew contacted Ljubljana Aerodrome Control, and from that time on the radiocommunications were uninterrupted and continuous. The conversation between the crew spoken sometimes too fast and a trifle garbled, and the controller spoken without any difficulty to understand is contained in the transcript of the R/T tape recording.

During the radiocommunications the controller supplied the crew with meteorological and other necessary landing information: "Wind is calm, visibility 5 kilometres, shallow fog over the runway is forming now, clouds 2/8 strato-cumulus 1 800 metres. QNH 1 011, QFE 968 millibars. Temperature 10 and dew-point also 10 degrees. Runway will be 31. After Dolsko make left pattern holding, descend down to 4 500 by QNH, report inbound." The crew acknowledged receipt of the information with: "Roger. We have runway 31. Over Dolsko descend 4 500 in the holding pattern. The QNH 1 011." When the pilot asked the controller if the ILS was operating, the controller answered that he had radar contact at a position 20 NM south-east from the airport and advised the crew to make an ILS approach to runway 31, and to report after descending to 4 500 ft QNH.

The crew acknowledged and reported they were at 4 500 ft and would call over Dolsko inbound for the outer marker and asked again if the ILS was operating and if it was serviceable. The controller answered affirmatively, adding that the ILS was working normally. He then gave the position "abeam Dol" and after that was acknowledged by the crew, he asked if they had contact with the runway. The crew confirmed that they had contact, and thereafter did not at any time indicate that they had lost contact, although it was implied by their request for a radar approach just before the accident occurred, and one minute later they reported having passed Dolsko continuing and descending towards runway 31. The controller acknowledged this information and requested the crew to "check final for runway 31", and gave the aircraft its position as 7 NM from touchdown on the centre line should be passing 3 300 ft, 3 300 ft, and repeated "check final for runway 31". The crew acknowledged this message and 1½ minutes later reported having passed the outer marker inbound. The controller issued clearance for landing and advised that he had set the approach and runway lights to maximum intensity. He then left the radar console and went to the light control console at the same time glancing towards the approach and the runway. He could not see the aircraft but the approach and runway lights were clearly visible. At that

moment, the crew requested radar assistance. The controller returned to the radar console and started to supply them with radar information. After giving the crew two aircraft positions of $3\frac{1}{2}$ NM and 2 NM from touchdown, he observed that the aircraft signal was turning to the right and gave a correction of 30° left. Observing that the aircraft did not make any correction, the controller informed the crew that its position was $1\frac{1}{2}$ NM from the touchdown, and asked the pilot whether he was making a short right turn to the radio beacon Menges. The crew did not reply, and there was no further contact with them although the controller continued calling. Radar contact was lost at 0047 hours local time on 1 September 1966 (2347 hours GMT on 31 August 1966) and when fire and smoke was seen from the tower, the controller gave the alarm and took necessary emergency measures. The rescue services, after 15 minutes, found the crashed aircraft on fire, in a wood, 2.8 km south-east of the threshold of runway 31 and 0.7 km north of the runway extended centre line.

1.2 Injuries to persons

Injuries	Crew	Passengers	Others
Fatal	6	92	
Non-fatal	1	18	
None			

1.3 Damage to aircraft

The aircraft was destroyed by the impact and subsequent fire.

1.4 Other damage

During the first and the final impact the aircraft damaged trees in a forest, and during the rescue and fire extinguishing, crops and plants in the neighbouring fields were destroyed.

1.5 Crew information

The pilot-in-command, aged 44, held a valid airline transport pilot's licence with type rating for Britannia 102 and had flown a total of 12 000 hours (5 486 hours as pilot, the remainder as radio officer), of which 517:45 hours were in Britannia 102 aircraft. His last instrument rating test was on 15 April 1966, and his last flight to Ljubljana was on 30 June 1966; during the last five months he had flown 506 hours in Britannia 102 aircraft and he had his last medical examination on 23 June 1966.

The co-pilot, aged 44, held a valid airline transport pilot's licence with type rating for Britannia 102 as first officer and had flown a total of 11 000 hours, of which 1 200 hours were in Britannia 102 aircraft. His last instrument rating test was in Britannia 102 aircraft on 28 August 1966; during the last six months he had flown 560 hours and he had his last medical examination on 26 April 1966.

The flight engineer, aged 37, held a valid flight engineer's licence for Britannia 102 aircraft.

The other four crew members were stewardesses.

1.6 Aircraft information

The aircraft was built at Filton in 1954, first air tested in January 1954, delivered to BOAC on 18 June 1957 and purchased by Britannia Airways on 18 November 1964.

Grand total hours flown by aircraft (excluding test flight) are 18 444. Hours flown since renewal of C. of A. (10 December 1965), excluding last flight, are 1 488.

Grand total of landings are 5 380. Landings made since last C. of A., renewal (10 December 1965) are 371.

The last mandatory check prior to accident was a Check 2 on 18 August 1966 when a current Certificate of Maintenance was issued (valid for 56 days or 500 hours).

On departure from Luton the aircraft was properly loaded, and carried sufficient fuel for the flight to Ljubljana. At the moment of the impact, the aircraft carried about 5 000 kg of fuel, and the possibility that the accident was caused by shortage of fuel was therefore eliminated.

No indications were found of any technical failures that could have affected the safety of the flight or have caused the accident. Up to the initial impact with the tree tops, the aircraft was airworthy, but after that probably uncontrollable because of damage to the elevators.

The weight of the aircraft during the approach was about 55 000 kg and the corresponding approach speeds, as indicated in the Britannia Airways operations manual, sec. 2.2.1.3 - 6.1, are:

flaps 15° - 160 kts
flaps 15° - 45°, gear down 140 - 120 kts

At the moment of impact the aircraft was not in the landing configuration - i.e. gear down and flaps 45° but in the field approach configuration - i.e. gear down and flaps 15°.

1.7 Meteorological information

During the approach and at the time of accident the meteorological situation was normal for landing, as seen from the information passed to the crew by the controller.

The forecaster in charge, the Chief of the Meteorological Section for Air Navigation of the Ljubljana Airport was present in the aerodrome tower together with the controller. Making observations, he also confirmed that the weather conditions were good; he had been observing the visibility and had had the approach and runway lights continuously in sight before the accident as well as the fire and smoke afterwards. The statement of the controller was identical.

The aircraft crew was informed that shallow fog was forming over the runway. In answer to a question from the controller, when the aircraft was about 12 NM from the aerodrome, in the vicinity of Dolsko, the crew indicated they had visual contact with the runway, and they did not subsequently report any loss of visual contact although this was implied by their request for a radar approach just before the accident. However, loss of

visual contact was not necessarily because of fog, it could have been due to obstruction by trees, when flying at an extremely low altitude. The formation of a thin layer of shallow fog, not higher than the tree tops, during the aircraft's approach was a typical condition for Ljubljana Airport, and does not normally cause a reduced visibility of the runway lights.

1.8 Aids to navigation

Approach and landing aids available at the Ljubljana Airport were:

ILS	PYE PTC - 1100
VHF/DF	Standard, PV - 1D
SRE/PPI/	Decca 424 MK II
VHF	PYE
NDB "DOL"	Redifon G - 175
NDB "MG"	Redifon G - 142

At the time of the accident all the equipment was in operation and there was no evidence of any malfunctioning.

1.9 Communications

Radiocommunications between the aircraft and ground station were continuous and without any technical interruptions up to the accident.

There were temporary departures from the ICAO procedures during the conversation. In addition, some of the R/T conversation from the crew was difficult for the controller, for the Commission of Inquiry and the accredited representative of United Kingdom, the State of Registry, and his advisers, who listened to it later, to understand - being spoken too fast and a trifle garbled. Therefore a copy of the recording of the R/T conversation was sent to London for examination and possible accurate interpretation.

So, the controller did not react to the crew's first indistinct request for radar guidance: "Will you keep your radar going, please", spoken too fast and a trifle garbled, because he thought it to be a part of communications between the crew members ("Will you keep your radio down, please"). This indistinct request could, only after considerable examination of the recording of the R/T conversation in Belgrade and London, be identified as "Will you keep your radar going, please".

1.10 Aerodrome and ground facilities

Ljubljana Airport lies 15 NM north-west of the city Ljubljana. Threshold 31 elevation is 364 m, and THR 13 elevation is 388 m. The RWY 31 slopes plus 0.8%. RWY 3 000 x 45 m.

The Airport installations include approach and runway lighting equipment for night landing on runway 31, as well as VASIS set to a 3° glide path. This lighting was operating normally at the time of the approach.

1.11 Flight recorders

The aircraft was not equipped with a flight data recorder and this fact complicated the accident investigation.

1.12 Wreckage

At the accident site it was observed that the aircraft had crashed through the trees to the ground and that many pieces of wreckage were caught up in the surrounding trees. After examining the wreckage, the suspicions of the commission led to it directing its attention to the possibility of the aircraft having struck some other obstacle before reaching the final accident site. A search on the ground in the direction from which the aircraft had made its approach revealed no evidence of a previous impact. However, because the commission was still not entirely satisfied, it obtained the use of a helicopter and examined a larger area of the terrain from the air. This examination revealed that the aircraft had cut the tops off some trees, situated along the extended centre line of the runway, over a distance of 320 metres and a width corresponding to the aircraft span. Some of the tree trunks cut off by the passage of the aircraft were found to be as much as 20 centimetres in diameter; amongst the damaged trees were found various small pieces of the aircraft skin torn off on impact.

The position of the initial impact with the tree tops was on the extended centre line of the runway, 3.8 kilometres from and about 5 metres below the level of the threshold and approximately 1.3 kilometres from the main wreckage site.

After examination of the circumstances of the accident, it became apparent that the aircraft first struck the tops of fir trees about 15 to 20 metres high on the edge of a forest while in level flight on the extended centre line of the approach to the runway. Following this initial impact it lifted clear of the trees then turned 70° to the right and crashed through other trees to the ground.

At the main (final) wreckage site marks on the trees indicated that the aircraft had been banked approximately 45° to the right and was descending at an angle of approximately 20° when it crashed. In its passage it uprooted some trees and cut through the trunks of others of up to 40 centimetres in diameter.

The aircraft disintegrated and caught fire on impact with the ground. Of the occupants 85 passengers and 6 crew members were killed on impact. One stewardess and 25 passengers survived, but 7 of them died later.

1.13 Fire

There was no evidence of any fire in flight before the first impact. The aircraft caught fire on impact and the fuselage was burnt from the nose through the passenger compartment. The fire and rescue service localised and extinguished the fire.

1.14 Survival aspects

The flight deck and the front half of the passenger cabin were completely demolished and disintegrated.

The factors involved in the escape of the survivors were, first, location towards the rear of the passenger compartment and, secondly, retention of or rapid recovery of consciousness with a degree of injury that did not prevent them getting away from the wreckage before it was engulfed by fire.

It is believed that, had rearward facing seats been fitted, there is a high probability that at least a few more passengers in the rear compartment of the aircraft might well have survived the initial impact with little or no incapacitating injury and thus been able to effect their own escape.

The fire engulfed the wreckage and may have cost the lives of some who might otherwise have survived although injured.

The findings of this accident reaffirm that any future advances in aircraft fuel system construction or fuel technology which would reduce the chances of either the outbreak of fire or its rapid spread would do much to reduce the loss of life in similar accidents.

1.15 Tests and research

During the investigation at the place of the accident it was found that navigator's altimeter was set to 1011 mb., i.e. to the QNH passed by the controller to the crew with the weather information. The other two altimeters, captain's and co-pilot's were recovered, badly damaged, from the aircraft wreckage and sent to England for examination together with the navigator's altimeter. When examined their respective millibar settings were found to be as follows:

captain's	- left pilot seat	1010.5 mb
co-pilot's	- right pilot seat	1005.5 mb
navigator's	-	1010.5 mb

Tolerances for the first and second altimeter settings are ± 2 mb., so neither of the pilots' altimeters was set to 968 mb., i.e. to the QFE that the controller passed to the crew with the meteorological information. The pilots probably did not monitor the altimeters as precisely as necessary for final approach and landing, and the captain omitted to reset his altimeter to the QFE, as required by the operations manual, so an error was possible because neither of the altimeters had been set to the QFE - 968 mb.

1.16 Reconstruction of the flight

The commission has reconstructed in detail the aircraft's approach path with altitudes and distances from the threshold and touchdown point of the runway. From calculations and diagrams drawn on a geographical flight projection, it can be seen that the aircraft's approach path to the airport, from first overflying "DOL" from the Olsevo direction up to the place of the accident, was probably as follows:

The aircraft overflew "DOL" for the first time at about 00.34 minutes 40 seconds, inbound from the Olsevo direction on a heading of about 200° at an altitude higher than 4 600 ft QNH. It then made a descending turn to the left on to about 310° at a distance of 20 NM from the airport and the controller made a radar contact (PPI) at about 00:39 minutes 20 seconds. Flying towards the runway, the aircraft had overflown "DOL" again at 00:42 minutes 10 seconds.

It can be stated with confidence that the aircraft's path from the direction of "DOL", i.e. 7 NM from the touchdown up to the place of the initial impact, coincided with the runway extended centre line.

From the evidence of witnesses along the flight path between "DOL" and the place of the initial impact, and the fact that it struck tree tops 3.8 NM from and 5 metres lower than the threshold, it is apparent that the aircraft was flying below the procedural altitudes, at least from the vicinity of "DOL", during its approach. The aircraft's configuration at the time of the accident - gear down, flaps 15° was, according to the Manual for the type, the normal field approach configuration; flap would normally be selected to 30° for final approach or descent on a glide path. On the basis of the traces of the initial impact with the tree tops, it appears that from "DOL" to OM "MG" the aircraft probably descended at 500 - 700 ft/min and that from OM "MG" the flight path was flatter or even level, because the traces of the initial impact with the tree tops showed that the aircraft had been flying level in a horizontal attitude at that time.

From the transcript of the R/T conversation and on the basis of the reconstructed flight path, it would appear that the crew expected to make a normal approach and probably performed it visually.

On the basis of the evidence the commission consider that the excessively low approach resulted from the captain unintentionally believing his altimeter to be set to the QFE, as required by the operations manual, when in fact it remained set to the QNH, while at the same time the first officer with the runway lights in sight was not monitoring his altimeter which was correctly set to the QNH. Alternatively, the captain may have intentionally left his altimeter set to the QNH instead of making the 43 millibar adjustment to the QFE, and then used the approach chart QFE heights as he would in normal circumstances with the QFE set. A third possibility is that the approach was made visually without reference to the altimeters.

2. - Analysis and Conclusions

2.1. Analysis

Main factors associated with the accident

The Britannia Airways operations manual, used by the crew, contains a detailed description of each pilot's duties and responsibilities - Vol. 1, General, Part 2, Flight Deck Management, Section G, page 2B, dated 1 February 1966, Attachment No. 15.3, paragraph G.2B.1, Instrument Setting - Procedure, point 1/ , 3/3, 3/5 and 3/6 require the pilots to set the altimeters in a specified way and to cross-check them over specified points or during the specified stages of the approach.

Paragraph G.2C.3 describes the duties and procedures to be adopted by the captain and co-pilot when making an instrument approach. It also lays down that for cross-check purposes full use should be made of all radio navigational aids available during an instrument approach.

Check list of the Britannia 102, 4.2.4., section 2, Part 1, dated 25 June 1962, Attachment No. 15 requires cross-checks and settings of altimeters during the different flight stages.

It was found that the aircraft had been approaching at altitudes much lower than those prescribed. All altimeters were found set very close to the QNH. Neither ADF was found set to the "DOL" or "MG" frequency, but since the crew advised the controller on passing the beacons it seems likely that the ADF equipments were correctly tuned and being used before the accident.

Of the two ILS/VOR receivers one was set to the Ljubljana ILS frequency and the other to the Zagreb VOR frequency. From the foregoing factors the commission could conclude that the crew, most probably, because of the good meteorological conditions and good visibility, made a visual approach without adequately cross-checking the altimeters, while maintaining their track visually and by reference to the ILS localiser and ADF sets.

The commission presumes that the first request of the crew for radar assistance, which was given immediately after the report of having passed OM "MG", was the moment when the crew experienced an unexpected situation. Unfortunately, this request was not understandable, and only after considerable examination of the recording of the R/T conversation, could it be identified as an interjection by the captain interrupting the First Officer's message to the controller and interpreted as "Will you keep your radar going, please".

A presumption is, that at this moment when the aircraft was about 4 NM from touchdown the crew lost visual contact with the approach lights and the request for radar assistance was given to guard against the aircraft deviating from the approach centre line as well as to check the range from touchdown. It is apparent that the crew were unaware that the aircraft was too low on the approach, because no evidence was found of any attempt to change to the emergency climbing configuration (full thrust, gear up, pull up), although the flaps may have been raised from 30° to 15° so as to fly level until contact was re-established. Most probably this was the last chance for the aircraft to climb to avoid the accident.

There were also some deviations from the ICAO standard R/T communication procedures by both the crew and the controller, but these did not cause the accident.

It was a night flight, and there were no visual land marks below the aircraft along the approach path to the airport; although the runway lights had been in sight, they were ahead of the aircraft and did not enable the pilots to discern the very low altitude of their approach.

The runway on Brniki Airport is not level, but slopes up 0.8 per cent and it is a well-known phenomenon that pilots in VMC at night approaching a runway which slopes upwards, have an impression of flying too high, although the glide path is correct. Conversely, pilots have an impression of flying too low if a runway slopes downwards. In addition, the effect at night of the runway light beams and light projection - "R/" Slope" - can give pilots an impression that they are not low. This effect and all possible consequences are described in the SAS Cockpit Bulletin No. 29/65 Oct. 22.

The pilots were required to fly intensively during the full summer season. The analysis of the flying times for the captain for 5 months and for the co-pilot for 6 months, as well as for both of them for the last 4 weeks before the accident flight, is given in this report. The fatigue limitations for airline transport pilots are not medically exactly defined, but accumulated fatigue can result from abnormal work/rest cycles with continuous change of place and country, together with rapid climatic changes, as well as the continuous changing of the day/night cycle. In this case, although long-term fatigue cannot

be completely excluded as a possible predisposing factor in the causation of the accident, no direct evidence that it played a part has been found.

2.2 Conclusions

(a) Findings

The technical investigation brought to light no evidence of any technical defect in the aircraft:

- the aircraft was airworthy, properly maintained and loaded as prescribed;
- no defect could be found in the parts of the control system which were recovered;
- the engines were operating normally up to the moment of the final impact;
- all the instruments and equipment recovered had, so far as condition after the impact allows such a statement, functioned properly;
- fuel remaining at the time of the accident was sufficient for this flight with approach and landing;
- no evidence could be found to suggest that the accident was caused by an explosion or fire on board;

The two pilots and the flight engineer held the necessary licences.

Post-mortem examination revealed no evidence likely to have contributed to the cause of the accident.

The aircraft was in the aerodrome traffic circuit on an approach to Ljubljana Airport, which had all the necessary facilities for IFR approach in normal operation.

The work of the ground personnel during the flight and approach to the Ljubljana Airport was within the standard limitations.

Radio communications between the controller and the aircraft, from the time the aircraft entered the aerodrome control zone up to the accident, were uninterrupted and generally within the normal ICAO Air Traffic Procedures in phraseology.

After the accident it was found that the altimeter of the pilot-in-command was set to the QNH and not to the QFE as necessary for a safe approach and landing.

(b) Cause or Probable cause(s)

The probable cause of the accident was that the pilot-in-command did not set his altimeter to the QFE-968mb in accordance with the information passed by the controller. However, the whole approach to the airport was made as if the altimeter had been set to the QFE, and resulted in the approach being about 1 250 ft lower than procedural safety altitudes, so that the aircraft crashed into the tree tops.

The co-pilot's altimeter was set to the QNH and he did not notice that the aircraft's approach was too low, because although it was a moonlight night he could not distinguish any visual land marks, which might have warned him of the low altitude, due to the nature of the tree covered terrain over which they were flying. As the altimeter error passed unnoticed by both pilots and because they were not carrying out cross-checks of the two altimeters in accordance with the relevant operations manual instruction, the error was not corrected by climbing to a safe altitude.

This disregard of the procedures laid down in the check lists and operations manual for approach and landing, may be explained by the fact that the approach was carried out on a moonlight night in calm weather and with visibility of approximately 12 NM, which reduced the crew's concentration on following precisely the prescribed procedures and checks.

The visual effect of the runway slope made the situation worse, giving the pilots a wrong impression of the aircraft's approach angle. The co-pilot's altimeter was found set to 1005.5 mb. The difference between the QNH and QFE passed to the aircraft was approximately equivalent to 1 000 ft - a figure which might have led to further confusion.

3. - Recommendations

All crew instructions relating to the procedures in flight must be precise and fully defined. We consider that the term "at a convenient time", relating to the setting of the altimeter from QNH to QFE by the pilot-in-command, as cited in the Britannia Airways operations manual - Flight Deck Management - G.2B.1.6/ , is insufficiently precise and may create an error.

VFR approaches at night by passenger transport aircraft should be forbidden unless all ground radio navigational aids available are used.

It is desirable that all turbo-prop aircraft be equipped with Flight Data Recorders.

If the approach and landing procedures are to be based on the QFE, then the crew must acknowledge its receipt by reading it back to the controller.