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ATSB TRANSPORT SAFETY INVESTIGATION REPORT
Aviation Occurrence Investigation – 200700368
Final

Engine in-flight shut down
256 km NW Melbourne, Vic.
5 February 2007
VH-EBY
Boeing Company 747-338

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Abstract

On 4 February 2007, the crew of a Boeing Company 747-338, registered VH-EBY, shut down the number-3 engine in flight, due to a fuel related problem.

Approaching the top of descent the crew noticed that the number-3 main fuel tank quantity indicator (FQI) was reading zero and that both fuel boost pump low pressure lights for that tank had illuminated. The crew then shut down the number-3 engine, broadcast a PAN broadcast and continued the flight for an uneventful landing at Melbourne.

An examination of the number-3 main fuel tank after landing, found that it was empty. An 'over-read' malfunction in the number-3 FQI had resulted in the crew believing there was a greater quantity of fuel remaining in the tank than was actually present. The planned quantity of fuel for arrival at Melbourne for the number-3 tank was 2,500 kg. An investigation of the incident conducted by the operator determined that the FQI malfunction was caused by either an electrical malfunction, water contamination or a combination of both.

The FQI fault was rectified and the aircraft returned to service.

The investigation also found that the operator's refuelling procedures were not able to accurately verify the base line quantity of fuel on board, or to alert the flight crew or line engineers to the consequences of an erroneous fuel quantity indicator system indication. The investigation reviewed the refuelling procedures for the operator's other fleet types to ensure serviceability of those installations. As a result of this occurrence, the operator is implementing a series of safety actions, including amending its refuelling procedures and conducting a risk assessment of its fuel management policies and procedures.

THE AUSTRALIAN TRANSPORT SAFETY BUREAU

The Australian Transport Safety Bureau (ATSB) is an operationally independent multi-modal bureau within the Australian Government Department of Infrastructure, Transport, Regional Development and Local Government. ATSB investigations are independent of regulatory, operator or other external bodies.

The ATSB is responsible for investigating accidents and other transport safety matters involving civil aviation, marine and rail operations in Australia that fall within Commonwealth jurisdiction, as well as participating in overseas investigations involving Australian registered aircraft and ships. A primary concern is the safety of commercial transport, with particular regard to fare-paying passenger operations.

The ATSB performs its functions in accordance with the provisions of the *Transport Safety Investigation Act 2003* and Regulations and, where applicable, relevant international agreements.

Purpose of safety investigations

The object of a safety investigation is to enhance safety. To reduce safety-related risk, ATSB investigations determine and communicate the safety factors related to the transport safety matter being investigated.

It is not the object of an investigation to determine blame or liability. However, an investigation report must include factual material of sufficient weight to support the analysis and findings. At all times the ATSB endeavours to balance the use of material that could imply adverse comment with the need to properly explain what happened, and why, in a fair and unbiased manner.

Developing safety action

Central to the ATSB's investigation of transport safety matters is the early identification of safety issues in the transport environment. The ATSB prefers to encourage the relevant organisation(s) to proactively initiate safety action rather than release formal recommendations. However, depending on the level of risk associated with a safety issue and the extent of corrective action undertaken by the relevant organisation, a recommendation may be issued either during or at the end of an investigation.

The ATSB has decided that when safety recommendations are issued, they will focus on clearly describing the safety issue of concern, rather than providing instructions or opinions on the method of corrective action. As with equivalent overseas organisations, the ATSB has no power to implement its recommendations. It is a matter for the body to which an ATSB recommendation is directed (for example the relevant regulator in consultation with industry) to assess the costs and benefits of any particular means of addressing a safety issue.

About ATSB investigation reports: How investigation reports are organised and definitions of terms used in ATSB reports, such as safety factor, contributing safety factor and safety issue, are provided on the ATSB web site www.atsb.gov.au.

FACTUAL INFORMATION

History of the flight

On 4 February 2007, a Boeing Company 747-338, registered VH-EBY, was being operated from Jakarta, Indonesia to Melbourne, Vic., on a positioning flight.

At approximately 256 km north-west of Melbourne, and shortly before the top of descent, the crew noticed that the number-3 fuel tank quantity indicator (FQI) was reading zero and that both fuel boost pump, low-pressure, lights for that tank had also illuminated. After completing the appropriate 'non-normal' checklist items, the crew shut down the number-3 engine. The crew assessed the proximity to alternative airports and a decision was then taken to continue to Melbourne. The crew broadcast a PAN[1] call to air traffic control and the flight continued for an uneventful landing at Melbourne.

The subsequent examination of the aircraft by maintenance personnel found no evidence of a fuel leak. A magnastick[2] check of the fuel remaining in the number-3 main fuel tank showed it to be empty. The fuel remaining in the other main tanks was reported as being 7,162 kg, which was greater than the minimum fuel required by the operator and Civil Aviation Order 20.2.5 to be aboard the aircraft at the end of the landing roll.

The examination of the aircraft's fuel quantity indicating system (FQIS) confirmed a malfunction had resulted in the number-3 FQI over-reading. The manner in which the malfunction occurred led the crew to believe there was a greater quantity of fuel remaining in that tank than was actually present. The examination determined that the malfunction was due to either an electrical problem, water contamination, or a combination of both. The number-3 FQIS fault was rectified and the aircraft returned to service.

Sequence of events

The aircraft had arrived at Jakarta 64 hours prior to the incident flight. Following arrival at Jakarta, the crew carried out an arrival fuel discrepancy check [3], which was determined to be within the prescribed limits. The fuel record sheet showed that the aircraft was then 'pre-refuelled' to a total of 50,390 kilograms. The refuelling engineer annotated a discrepancy of +669 kg between the 'before refuelling amount' and the total 'after refuel amount' on the fuel record sheet. This figure was within the allowable discrepancy of +/- 3000 kg.[4].

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1 Communication phraseology used to indicate that an aircraft is experiencing an urgent situation and requires priority facilitation.

2 Magnastick (similar to dipstick) is a physical method of determining the quantity of fuel in the aircraft fuel tanks.

3 Arrival discrepancy check compares the quantity of fuel used for the flight as indicated by the Fuel Quantity Indicating System (FQIS), with the quantity of fuel used for the flight as indicated by the 'Fuel used' gauges.

4 The allowable discrepancy is a comparison between the uplift of fuel as measured by the flight deck fuel quantity indicators, and the uplift fuel as measured by the refuelling tanker gauges.

The station engineer at Jakarta advised that the aircraft was refuelled shortly after it arrived and also that the purpose of pre-refuelling was to reduce the possibility of water contamination, by displacing the air space in the fuel tanks, and also to allow any free water that may be present in the fuel to settle prior to preparing the aircraft for the next flight.

Maintenance personnel could not recall if a water drain had been conducted at any time after this pre-fuel.

During the subsequent 64 hours between the pre-fuelling and the final up-lift of fuel for the flight to Melbourne, heavy and continuous rain was reported at Jakarta.

The operating flight crew's final up-lift fuel requirement for the flight to Melbourne was for 64,200 kg. The fuel records showed that the check of the quantity on board prior to the addition of the final uplift was 52,820 kg, which was an increased (cockpit gauges) indication of 2,430 kg since the pre-fuelling had been completed.

At the completion of the final uplift, the total fuel quantity displayed by the cockpit FQI gauges was 65,100 kg. There was a discrepancy of -334 kg between the cockpit gauges and the uplift quantity indicated by the fuel tanker gauges. The discrepancy was within the operators published limits of +/- 3,000 kg.

The flight engineer for the Jakarta to Melbourne flight had conferred with a ground engineer prior to departure from Jakarta concerning the company operational requirements for a magnastick check at the completion of the final refuelling. After referring to the operational documentation, it was concluded that a magnastick check was not required.

During the climb and again at about the top of climb, the flight engineer observed the number-3 main fuel tank FQI display momentarily decrease by approximately 3,000 kg. This decrease was combined with the illumination of the fuel configuration light, before the FQI returned to display the higher value. The inbuilt monitoring system for the FQI did not display or log an error code.

The crew discussed the indication problem and undertook numerous checks in order to confirm the serviceability status of the FQIS. They determined that the fluctuating indications were probably due to an intermittent or unreliable number-3 main tank FQI.

Operator's investigation

The operator subsequently conducted a detailed investigation into the incident. In addition to determining the reasons for the FQIS malfunction, the investigation also sought to determine why the operator's refuelling procedures in place at the time had failed to identify and contain the effects of the erroneous indication by the FQIS.

The investigation found that the number-3 main tank fuel quantity indicator over-read due to an electrical malfunction, water contamination, or a combination of both.

The investigation also identified several other factors which had contributed to the development of the incident. These included a recent revision to the operator's refuelling procedures, which introduced a change to the method by which the

quantity of fuel remaining on board the aircraft was determined prior to refuelling. In part, the revised procedure assumed a serviceable FQIS.

Prior to the introduction of the revised refuelling procedures, the quantity of the fuel on board (arrival fuel) was determined by a cross check of the fuel used, the arrival fuel, and the fuel used during the period the aircraft spent on the ground. The revised refuelling procedures allowed for the use of the FQIS reading (cockpit quantity gauges) immediately prior to refuelling with no reference to a previous reading.

The operator's Fuelling Maintenance Manual (FMM) provided the engineering personnel with procedures for refuelling aircraft. The operator's FMM superseded the manufacturer's requirements regarding refuelling procedures. In part the FMM stated:

> Periodic draining of fuel tank sumps is essential for removal of free water from fuel tanks for an aircraft ground time of greater than 6 hours, - a sump drain of all tanks which are to be fuelled should be conducted prior to refuelling and after time has been allowed for settling out of any water.

The aircraft manufacturer's guidance for the prevention of water contamination recommended that operators drain the fuel tank-sumps regularly. The guidance further advised that:

> Removal of water will help minimise microbial growth that exists at the fuel/water interface. Microbial growth can cause fuel system degradation including clogged engine filters, fuel quantity indication problems, and eventually structural corrosion.

This guidance was similar to that provided by the manufacturer of a second major aircraft type in the operator's fleet, regarding the prevention of water contamination of the fuel. This second manufacturer further advised "therefore the first consideration in prevention is minimising water content in the fuel tank system".

The operator's investigation found that certain of the recent revisions to the operator's refuelling procedures were described to flight crew as 'a significant change in policy'. A summary of the changes from the previous procedures included:

- the fuel on board prior to refuelling was to be referenced to the fuel quantity indicator reading immediately prior to the start of refuelling or the arrival fuel
- the allowable discrepancy was changed to a fixed value
- the 747-338 fleet requirements for a magnastick check to be carried out after greater than 36 hours on the ground was extended to greater than 72 hours on the ground
- a post flight arrival check of fuel remaining by gauges compared to fuel used was implemented across all fleets. (This arrival check had been in operation for approximately 6 months prior to the event flight).

The operator had a risk management process which included a documented process for identifying operational hazards or deficiencies when changing operational policies and procedures. This process was not used in the development of the revised refuelling procedures. In addition, a risk assessment was not completed for

the procedures before they were promulgated, as required by the operator’s risk management process.

ANALYSIS

The evidence indicated that the number-3 tank fuel quantity indicator (FQI) over-reading was due either to an electrical malfunction, or water contamination, or a combination of both.

Maintenance personnel were not able to recall if a water drain was carried after the aircraft arrived at Jakarta or prior to departure for Melbourne. If a water drain check was done during this period, it would have minimised the opportunity for water or moisture to have been a factor in the over-reading anomaly of the number-3 FQI.

Irrespective of the reason/s for the technical fault in the fuel quantity indication system (FQIS), had the actual quantity of fuel in the main tanks been established after arrival in Jakarta, using a cross check similar to that required in the operator's FMM procedures prior to revision, it is reasonable to expect that the quantity indicating error for the number-3 tank would have been identified. Therefore, the cause of the malfunction was of lesser importance than the fact that the revisions to the refuelling procedures had significantly reduced the opportunity for the flight crew or engineering personnel to be alerted to, or identify, any malfunction to the FQIS.

In part, the revision to the operator's refuelling procedures assumed a serviceable FQIS for establishing the reference base line fuel quantity on board prior to the refuelling. The revised procedures were also based on the assumption that should the FQIS develop a fault, the system would not indicate a larger quantity than actually present on board the aircraft. In the case of the incident flight, both assumptions were not valid due to the malfunction in number-3 main tank FQI.

If the operator's documented procedures for identifying operational hazards or deficiencies had been used in the development of the revised refuelling procedures, and had the revision been submitted for risk assessment prior to promulgation, it would have provided another opportunity to identify any deficiencies in the revised procedures.

FINDINGS

From the evidence available, the following findings are made with respect to the fuel related event involving Boeing 747 aircraft, registered VH-EBY, which occurred approximately 256 km north-west of Melbourne, Vic. on 5 February 2007. They should not be read as apportioning blame or liability to any particular organisation or individual.

Contributing safety factors

- A malfunction in the aircraft's fuel quantity indication system (FQIS) resulted in the number-3 main tank fuel quantity indicator (FQI) over-reading and in a reduced fuel load for the flight.
- The cause for the over-reading was due either to an electrical malfunction, or water contamination or a combination of both.
- A recent revision to the company refuelling procedures had extended the time between the required fuel water drain checks. (*Safety issue*)
- The revised procedures introduced a change which assumed a serviceable FQIS as part of the process for determining the reference baseline fuel quantity. (*Safety issue*)
- The operator's revised procedures assumed that should the FQIS develop a fault, the system would not indicate a greater quantity than was actually present on board the aircraft.
- The operators documented process for identifying hazards or deficiencies was not used in the development of the revised refuelling procedures.
- The revised refuelling procedures did not undergo a risk management assessment as required by the operator's policy.

SAFETY ACTION

The safety issues identified during this investigation are listed in the Findings section of this report. The Australian Safety Bureau (ATSB) expects that all safety issues identified by the investigation should be addressed by the relevant organisation(s). In addressing these, the ATSB prefers to encourage relevant organisation(s) to proactively initiate safety action, rather than issue formal safety recommendations or safety advisory notices.

All of the responsible organisations for the safety issues identified during this investigation were given a draft report and invited to provide submissions. As part of that process, each organisation was asked to communicate what safety actions, if any, they had carried out or were planning to carry out in relation to each safety issue relevant to their organisation.

Aircraft operator

As a result of this occurrence, the aircraft operator's safety department issued a series of safety actions and recommendations as a result of its investigation findings. These safety actions and recommendations included the following:

- Maintenance Memo M07-0256 approved 31 July 2007, Pre-fuelling of aircraft, included the following caution: "The fuel quantity gauge totals must not be used as the basis for establishing the 'fuel on arrival' figure, unless checked against the technical log 'ARR Fuel' figure and adjusted for subsequent usage by the APU, engine ground running and fuel maintenance activity".
- Maintenance Memo MO7-0256 also requested a change to the applicable aircraft fuelling maintenance manual (FMM).
- In response to the omission of a formal risk assessment for the change in operating policy by the operator's flight and engineering groups, the operator's senior management directed that risk assessments be undertaken of the operator's fuel management policies and procedures.
- A review of the operator's water drain policy and procedures, to ensure adequate protection against fuel contamination, was conducted and the operator's FMM has been amended to reflect the new requirements.