Australian Government

Australian Transport Safety Bureau

Fuel imbalance involving Boeing 767-3JHF, VH-EXZ

Auckland Airport, New Zealand, on 27 July 2019

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Postal address: PO Box 967, Civic Square ACT 2608
Office: 62 Northbourne Avenue Canberra, ACT 2601
Telephone: 1800 020 616, from overseas +61 2 6257 2463
Accident and incident notification: 1800 011 034 (24 hours)
Email: atsbinfo@atsb.gov.au
Website: www.atsb.gov.au

Addendum

Page	Change	Date

Safety summary

What happened

While the Boeing 767, VH-EXZ, was taxiing for departure from Auckland an imbalance in the fuel load between the left and right main tanks developed while the centre tank was providing fuel to both engines. That imbalance triggered the FUEL CONFIG advisory alert message. In response, the flight crew considered whether there was a fuel leak and, having determined this was not the case, decided to depart and correct the out-of-balance condition airborne.

Once airborne, the flight crew delayed the procedure to rebalance the fuel until the centre tank fuel had been depleted. As a result, the fuel imbalance increased to 2.6 t, a weight difference in excess of the fuel imbalance limitation published in the operator's policy and procedures manual. On arrival at Sydney, the flight crew verbally notified the maintenance personnel of the imbalance but did not enter it into the technical log. The return flight was not loaded with centre tank fuel. The operator's maintenance organisation did not become aware of the fuel imbalance issue until about 3 days after the occurrence.

What the ATSB found

The ATSB found that the fuel imbalance was the result of abnormal fuel system behaviour, due to a fault within the fuel system, which resulted in fuel being fed into the right main tank from the centre tank. As the imbalance occurred before take-off, a procedure within the Minimum Equipment List (MEL) required the flight crew to action the relevant non-normal checklist and if discontinuation of the flight was not required, then consult the MEL to determine whether maintenance action was required.

Application of the MEL would have required the aircraft to return for maintenance action.

The flight crew had differing knowledge of the MEL requirements however, they shared a common belief that the risk was low enough for the flight to proceed. Consequently, having consulted only the non-normal checklist, the aircraft departed Auckland.

Airborne, the flight crew identified that the abnormal fuel system operation was the result of fuel being pumped into the right main tank. Additionally, the flight crew continued to monitor for a fuel leak and noted that the aircraft's handling did not appear to be affected by the imbalance. Further, as fuel system guidance and the low priority of the FUEL CONFIG advisory alert message indicated minimal risk from a fuel imbalance condition, the flight crew chose to delay rebalancing. Consequently, the flight crew did not determine whether there was full access to the remaining fuel until they had recommenced the FUEL CONFIG non-normal procedure.

The fuel system unserviceability was verbally notified to engineering, however, contrary to the requirements of the operator's policy and procedures manual, it was not entered into the technical fault log. This delayed maintenance corrective action, and likely hampered determination of the cause of the imbalance.

What has been done as a result

The aircraft's operator advised the ATSB that an amendment to the MEL has been drafted to include clarification as to crew actions in the event of an Engine Indication and Crew Alerting System (EICAS) message between off-blocks and take-off. This amendment will be situated in the early part of the MEL Introduction section.

The operator has also stated that it will alert flight crew to the procedural requirement through notification of the MEL amendment.

Safety message

This occurrence highlights the value of flight crews being fully conversant with operating procedures, particularly those related to aircraft unserviceability. Those procedures are critical to the safety of flight operations.

It is also important that any unserviceability is recorded in the aircraft's technical log to ensure that it is addressed and to provide future reference in case of further, or related, instances.

Contents

The occurrence

At 1154 New Zealand Standard Time[1] on 27 July 2019, a Tasman Cargo Airlines Boeing 767-3JHF, registered VH-EXZ, was taxiing for departure from Auckland, New Zealand, for a freight service to Sydney, New South Wales. As the aircraft was entering the runway for departure, the Engine Indication and Crew Alerting System (EICAS) displayed a FUEL CONFIG advisory alert message on the primary EICAS display. The message was the result of an imbalance condition that exceeded a pre-set limit between the left and right main fuel tanks.

The flight crew commenced their duty at about 0930, and consisted of the aircraft captain, who occupied the left seat and was the pilot monitoring (PM), and the first officer, who occupied the right seat and was the pilot flying (PF).[2] The flight, which was scheduled to depart at 1145, was the first of two sectors for the aircraft and flight crew that day.

The flight was dispatched as an EDTO flight[3] authorised to operate up to 120 minutes from an alternate aerodrome. The aircraft was loaded with about 21 t of fuel, with 8.0 t in the centre tank and the remainder distributed evenly between the left and right main tanks. The flight crew arrived early at the aircraft and started the aircraft's auxiliary power unit (APU) before commencing pre-flight duties.

Engine start was commenced at 1137 and completed at 1140. Following completion of the engine start:

- the fuel panel was properly configured for flight
- fuel was distributed as 6.6 t in the left main tank, 6.5 t in the right main tank and 7.9 t in the centre tank.

Taxi for departure commenced shortly thereafter.

The first officer reported that, on approaching the holding point for the departure runway the FUEL CONFIG light on the fuel panel started to intermittently illuminate.[4] The cause of the light was identified as an imbalance between the left and right main tanks, with the left tank low. At that time, the first officer attributed the imbalance to the refuelling being out-of-balance and extended APU use during pre-flight.

At 1156, just after the flight crew had completed departure procedures and the aircraft cleared to enter the runway, the FUEL CONFIG light illuminated. This triggered the FUEL CONFIG advisory alert message. The left tank was indicating 6.6 t, the right tank 7.7 t, while the centre tank had decreased to 6.2 t.

The flight crew established that the fuel panel was correctly configured and assessed that the imbalance was not due to a fuel leak—through comparing the fuel totaliser and the flight management computer's calculated fuel remaining figures (see the section titled *FUEL CONFIG non-normal checklist)*. They began completing the non-normal checklist and then decided to continue with the departure and address the imbalance condition once airborne because:

- rebalancing required changes to the fuel panel (an action that the captain did not wish to do immediately prior to take-off)
- the imbalance was not critical to departure

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1 New Zealand Standard Time (NZST): Coordinated Universal Time (UTC) + 12 hours.

2 Pilot Flying (PF) and Pilot Monitoring (PM): procedurally assigned roles with specifically assigned duties at specific stages of a flight. The PF does most of the flying, except in defined circumstances; such as planning for descent, approach and landing. The PM carries out support duties and monitors the PF's actions and the aircraft's flight path.

3 Extended Diversion Time Operations (EDTO): Any operation by an aeroplane with two or more turbine engines where the diversion time to an en-route alternate aerodrome is greater than the threshold time established by the State of the Operator. For VH-EXZ, the threshold time was 60 minutes.

4 The fuel panel (see Figure 1) is located on the right side of the overhead instrument panel, immediately above the right flight crew seat.

- the departure was imminent.

The aircraft departed Auckland at 1200.

Post departure, the flight crew reassessed the fuel imbalance condition. The captain stated that the fuel imbalance did not cause any controllability issues and that the aircraft trim remained at zero for the duration of the fuel imbalance event. The captain continued to check for a fuel leak airborne, and stated that at no time was there any indication of a fuel leak. It was, however, noted that the source of the imbalance was fuel being fed into the right tank.

The first officer reported that, early in the climb, the imbalance was identified to be the result of abnormal operation of the fuel system. While the centre tank fuel quantity was decreasing as expected, and the left main remained stable, the right main was unexpectedly increasing.

The captain stated that, as the rebalancing procedure involved making changes to the fuel panel, which in turn would have resulted in the triggering of the FUEL CONFIG advisory alert message, it was decided to delay rebalancing until the centre tank was nearly empty. As a result, the FUEL CONFIG non-normal procedure that was to be actioned in response to the alert message was not commenced until about 30 minutes after departure. During that period, the imbalance between the left and right main tanks continued to increase. The aircraft reached its cruising altitude of FL 360[5] at 1216.

The flight crew reported that rebalancing of fuel system commenced when the fuel pressure low lights illuminated on the centre tank's left and right fuel pumps, indicating that the centre tank quantity had reduced to about 400 kg. At that time, the imbalance between the left and right main tanks was 2.6 t. Rebalancing commenced at 1229, with the flight crew actioning the FUEL CONFIG non-normal checklist. When the left and right main tanks were re-balanced, the fuel panel was returned to a normal configuration. The aircraft's main fuel tanks remained balanced for the remainder of the flight.

On arrival into Sydney, the flight crew reported the abnormal fuel system behaviour by telephone to the maintenance engineer in Auckland who had dispatched the aircraft. It was also discussed with the maintenance engineer who met the aircraft in Sydney. However, no maintenance action to address the fuel imbalance issue was carried out in Sydney and the defect was not entered into the aircraft's maintenance log prior to the return leg to Auckland.

Fuel was not loaded into the centre tank for the return flight to Auckland. The flight crew reported that, on that return flight, the fuel system operated normally. After arrival in Auckland, the fuel imbalance issue from the previous sector was again not entered into the aircraft's maintenance log. Maintenance action concerning the imbalance did not commence until 3 days later.

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5 Flight level: at altitudes above 13,000 ft in New Zealand, an aircraft's height above mean sea level is referred to as a flight level (FL). FL 360 equates to 36,000 ft.

Context

Pilot information

The captain held an Air Transport Pilot License (Aeroplane) and a Class 1 medical certificate. The pilot's flight experience totalled approximately 19,100 hours, of which 176 hours were on the Boeing 767 (B767). In the 90 days preceding the occurrence, the pilot had flown about 55 hours on B767 type aircraft.

The first officer held an Air Transport Pilot License (Aeroplane) and a Class 1 medical certificate. Their flight experience totalled approximately 9,000 hours, of which 450 hours were on the B767. In the 90 days before the occurrence, the pilot had flown about 105 hours on B767 type aircraft.

Both pilots reported being well rested and alert at the commencement of duty for the occurrence flight and there was no evidence to indicate a risk that fatigue affected the flight crew's performance.

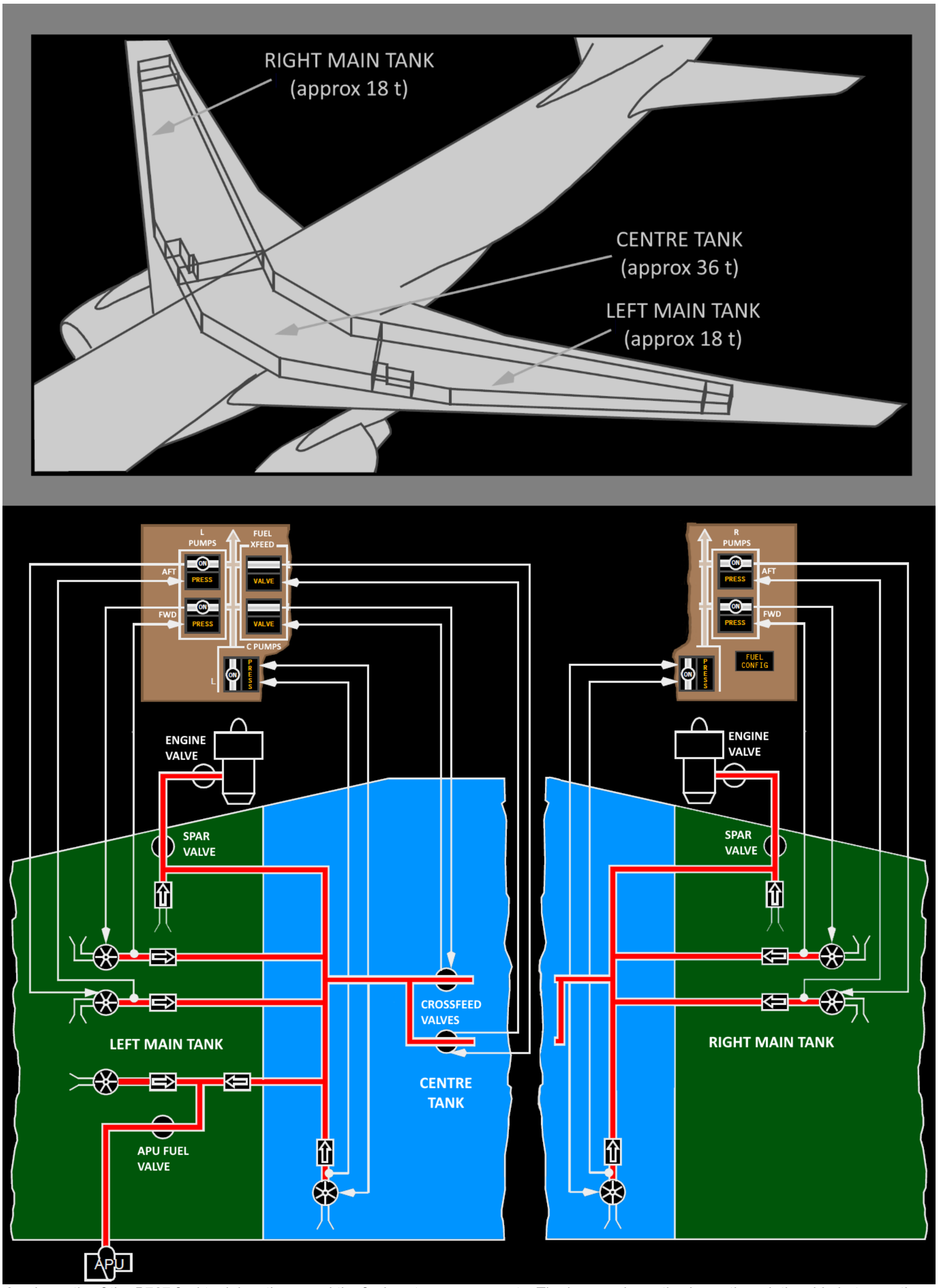
Aircraft information

Fuel system

The B767 fuel system (Figure 1) comprised:

- three fuel tanks—the centre tank, and the left and right main tanks
- two fuel pumps in each tank
- a fuel quantity system that determined fuel density and quantity to display fuel in kg
- a fuel crossfeed system that could supply fuel to an engine from the opposite side fuel tank
- fuel panel controls.

Figure 1: The B767 fuel system



A schematic of the B767 fuel tank locations, and the fuel system components. The lower schematic shows the relationship between the left and right wing tank and centre tank, the fuel pumps, crossfeed system and the controls for those systems.

Source: Boeing, modified by ATSB.

The Flight Crew Operating Manual (FCOM) description of the fuel system included the following with respect to the:

- fuel tank pump outputs:

> The two center tank fuel pumps have greater output pressure than the left and right main tank fuel pumps. When all six pumps are operating, the center tank pumps override the left and right main tank pumps so that center tank fuel is used before [the] left or right main tank fuel.

- FUEL CONFIG light:

> When the fuel quantity in [the] left and right main tanks differ by 900 kilograms (plus or minus 200 kilograms) or center fuel pump switches are OFF with more than 500 kilograms in the center tank, the FUEL CONFIG light illuminates and the EICAS advisory message FUEL CONFIG is displayed.

- fuel imbalance:

> Fuel balancing is accomplished by opening the crossfeed valves and turning off the fuel pump switches for the left or right main fuel tank that has the lowest quantity. Fuel balancing may be done in any phase of flight.

- FUEL CONFIG Engine Indication and Crew Alerting System (EICAS) advisory alert message, which was triggered when:

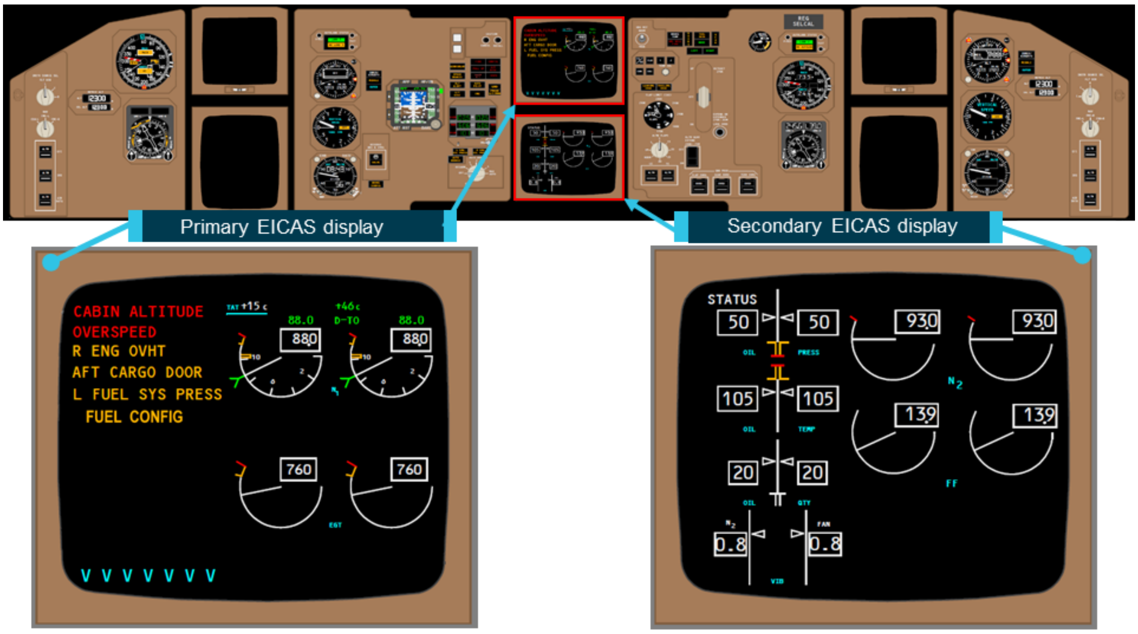
> Both center pump switches are OFF with fuel in the center tank, or a fuel imbalance between main tanks, or the fuel quantity is low in a main tank.

Fuel for the aircraft's Auxiliary Power Unit (APU) was fed from a pump located in the left main tank.

Engine Indication and Crew Alerting System

The EICAS provides flight crew with aircraft engine and systems information. It also provides an alerting system to the flight crew about aircraft configuration issues, or system faults and failures. The primary feature of the EICAS are two vertically-mounted, centrally-located displays on the forward instrument panel (Figure 2). The EICAS also incorporates visual and aural alerting systems.

Figure 2: Front instrument panel



B767 front instrument panel showing the primary and secondary EICAS screen locations, with expanded view of both. The primary EICAS is displaying warning, caution and advisory level messages.

Source: Boeing modified by ATSB.

EICAS alerts are displayed on the primary EICAS display, with type-specific visual and aural alerts. The type of alert that EICAS will produce depends on the nature of the issue and its importance or priority. There are four types, or categories of EICAS alerts. Ranked in order of priority, these are:

- time-critical warning, which required immediate crew awareness and immediate corrective action
- warning, which required immediate crew awareness and corrective action
- caution, which required immediate crew awareness and for which corrective action may be required
- advisory, which required routine crew awareness and for which corrective action may be required.

The specific alert may also require performance of a non–normal checklist. Non-normal checklists were contained within the Quick Reference Handbook (QRH) and were referenced using the alert message displayed to the flight crew.

Aircraft operating limits

The introduction to the 'Limitations' chapter of the FCOM stated that it contained Airplane Flight Manual[6] (AFM) limitations, AFM operational information and non-AFM operational information. The introduction stated that limitations and operational information were included within that chapter if they were operationally significant or prescribed under regulation. Limitations were not included where they were incorporated into normal, supplementary, or non-normal procedures, or were shown on a placard, display or other marking.

The Limitations chapter did not include any fuel system limitations relevant to the fuel imbalance event, although the FUEL CONFIG advisory alert message was triggered for an imbalance that was 900 kg, plus or minus 200 kg.

Operational information

The FCOM contained the normal and supplementary procedures, and the QRH detailed the non-normal checklists, necessary for the operation of the aircraft. The pre-eminent source of operations policy and procedure was the Policy and Procedures Manual (PPM). The PPM contained specific procedures, instructions and information required by the Civil Aviation Safety Authority (CASA) that were necessary to ensure the safe conduct of flight operations. Guidance material relevant to the operation of the aircraft was also found in the Flight Crew Training Manual (FCTM).

Normal procedures

FCOM normal procedures

The normal procedures section of the FCOM contained pre-flight and before start procedures that contained specific fuel system configuration selections required of the first officer. These procedures identified that, when there was fuel in the centre tank, the fuel system was to be configured with (see Figure 1):

- the FWD and AFT fuel pump switches for the left and right main tanks ON
- both FUEL XFEED valve switches OFF
- the centre tank left pump and right pump (CTR L and CTR R) switches ON.

The climb and cruise procedures included procedures for when the centre tank emptied of fuel, and/or the CTR L or CTR R FUEL PUMP EICAS advisory alert message was displayed.

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6 The AFM is part of the certification documentation for the aircraft type. An aircraft's Type Certificate, issued by the certifying state, includes the Type Certificate Data Sheet (TCDS). The TCDS identifies the certification basis, the operating conditions, and limitations etc that have been specified as mandatory in the approval of the type design. The AFM contains those limitations and procedures necessary for safe flight and operation of the aircraft.

FCOM supplementary procedure—fuel balancing

The supplementary procedures section included a fuel balancing procedure. This procedure commenced with advice to use the 'Fuel Leak Engine' procedure if a fuel leak was suspected. It then stated the following:

> When the fuel quantities in left main and right main tanks differ by an appreciable amount:
>
> Crossfeed switches (both)...ON
>
> Fuel pump switches (low quantity tank) ....OFF
>
> When fuel load balanced:
>
> Fuel pump switches ....ON
>
> Crossfeed switches (both)...OFF

PPM—priority of the AFM

Chapter 14 of the PPM provided information on the operator's operations manual suite. That chapter included the following:

> The Aircraft Flight Manual is an integral part of the Certificate of Airworthiness of the aircraft. It will be carried in the aircraft at all times.
>
> The PIC is required to comply with requirements, instructions, procedures or limitations concerning the operation of the aircraft as set out in the Aircraft Flight Manual.
>
> In the unlikely event that the requirements of the Aircraft Flight Manual conflict with the requirements of any manual from the [Tasman Cargo Airlines] TCA manual suite, the requirements of the Aircraft Flight Manual shall take precedence.

PPM—fuel system limitations

The normal operations section of the PPM contained procedures related to the fuel system. Included within that section were requirements concerning fuel usage with fuel in the centre tank. With respect to a lateral fuel imbalance, that section stated:

> The maximum allowable fuel imbalance between left and right main tanks for all operations is 1,134 kgs when the total main tank fuel is 21,772 kgs or less...

The operator advised that the PPM fuel imbalance limitations were sourced from the B767 AFM for VH-EXZ. Also sourced from the AFM, the PPM detailed a fuel loading schedule, which required the wing tanks to be filled before fuel was loaded into the centre tank. That schedule permitted 10.0 t of fuel to be loaded into the centre tank with less than full main tanks, provided specific fuel jettison capability and maximum aircraft zero fuel weight criteria were met.

PPM—loading of the centre tank fuel

As the operator's B767 sectors were exclusively between New Zealand and the Australian east coast, normal fuel loading resulted in the centre tank not being utilised. The operator identified that the aircraft's capacity for long range operations could be limited by the serviceability of the centre tank system if that system was not regularly used. As the regular schedule was for weekday evening return flights from Auckland to Sydney, which were curfew limited, and a Saturday daylight flight, the operator commenced a policy to load 8 t of fuel into the centre tank on the Saturday flights only.

Non-normal procedures

FUEL CONFIG non-normal checklist

The FUEL CONFIG EICAS message was classified as an advisory alert, which was triggered when one or more of the following conditions occur:

- Both centre pump switches are off with more than about 500 kg of fuel in the centre tank
- A fuel imbalance of 900 kg ± 200 kg between the left and right main tanks

- The fuel quantity is low, less than around 1,000 kg, in a main tank.

The QRH checklist for the FUEL CONFIG advisory alert message stated the following:

> 1 If an engine has low fuel flow and unusual engine indications, a fuel imbalance may show due to engine damage instead of a fuel leak.
>
> 2 The FUEL CONFIG message may be caused by an engine fuel leak, center pump switches off incorrectly, an imbalance, or low fuel.
>
> 3 A fuel leak should be suspected if one or more of the following are true:
>
> The total fuel quantity remaining is less than the planned fuel remaining.
>
> An engine has excessive fuel flow.
>
> On PROGRESS page 2, the totalizer is less than the calculated fuel.
>
> The TOTALIZER fuel is the sum of the individual tank quantities.
>
> The CALCULATED fuel is the totalizer value at engine start minus fuel used.
>
> Fuel used is calculated using the engine fuel flow sensors.

The QRH checklist then presented two options to manage a FUEL CONFIG advisory alert:

- If a fuel leak was indicated, the flight crew were directed to conduct the 'Fuel Leak Engine' checklist
- If a fuel leak was not indicated, the checklist continued with the steps required to bring the fuel tanks back into balance. These steps were the same as the fuel balancing supplementary procedure. Finally, the checklist required consideration with respect to low fuel quantity, a condition that was not relevant to this occurrence.

FCTM—fuel balance guidance

The FCTM included the following regarding fuel balance:

> The primary purpose of fuel balance limitations on Boeing airplanes is for the structural life of the airframe and landing gear and not for controllability. A reduction in structural life of the airframe or landing gear can be caused by frequently operating with out-of-limit fuel balance conditions. Lateral control is not significantly affected when operating with fuel beyond normal balance limits. The primary purpose for fuel balance alerts is to inform the crew that imbalances beyond the current state may result in increased trim drag and higher fuel consumption. The FUEL CONFIGURATION [non normal checklist] should be accomplished when the fuel balance alert is received.

The FCTM also stated that the flight crew should consider, among other things, that:

> during critical phases of flight, fuel balancing should be delayed until workload permits. This reduces the possibility of crew errors and allows crew attention to be focused on flight path control.

The take-off is a critical phase of flight.

Boeing Aero magazine—fuel imbalance

In 2000, Boeing published an article on in-flight fuel imbalance in the quarterly Aero magazine.[7] That article contained the following information about fuel imbalance indications:

> With the introduction of the two-crew member flight deck...fuel system automation was incorporated to relieve the flight crew of most fuel management tasks. Fuel use is monitored electronically by the [fuel quantity indicating system], fuel management system, or flight deck indication system. These systems monitor fuel usage and annunciate a fuel imbalance condition in the flight deck when the imbalance reaches a specific value...No action is required by the flight crew unless a fuel imbalance indication is displayed, which the flight crew should address on a time-available basis in accordance with operations manual procedures...

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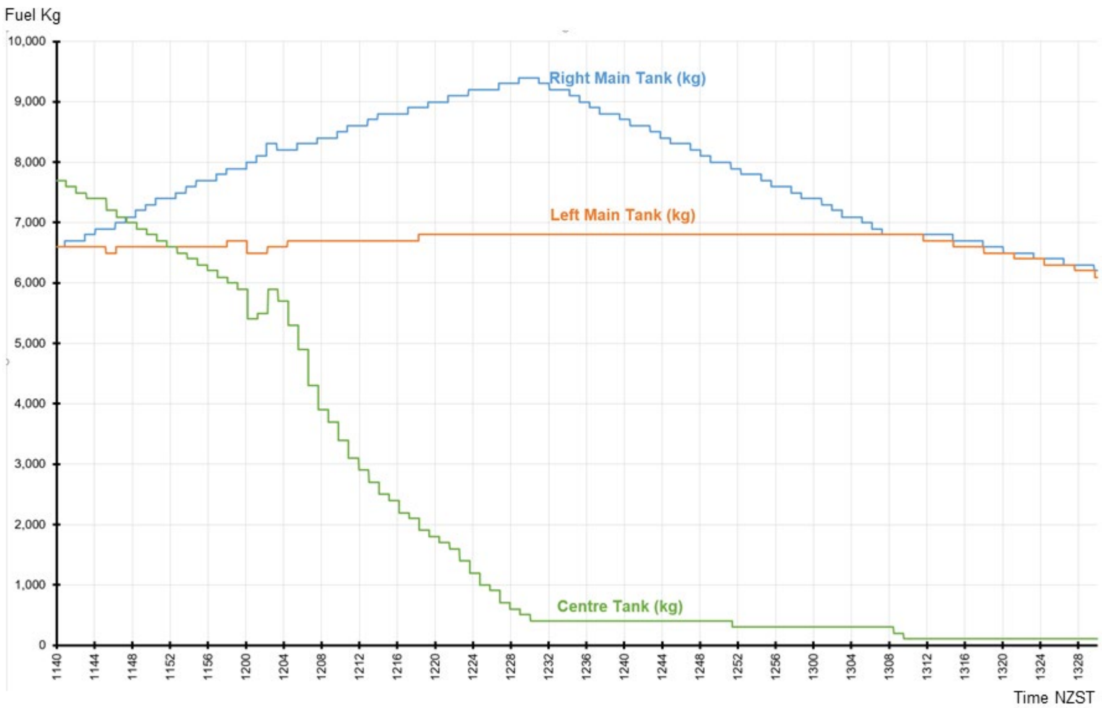
7 See https://www.boeing.com/commercial/aeromagazine/aero_09/about.html.

> The amount of fuel imbalance allowed before the indication is displayed minimizes additional fuel consumption caused by lateral trim drag and limits the amount of fuel balancing that the flight crew must accomplish. As the fuel becomes unbalanced, lateral trim is required to maintain wings-level flight. The lateral trim requirement increases airplane drag and consequently increases fuel consumption. Waiting until the indication to balance fuel is displayed limits the number of times the fuel must be balanced without significantly increasing fuel consumption.
>
> An indicated fuel imbalance does not affect the ability of the airplane to safely complete its scheduled flight. The flight crew should accomplish the fuel imbalance procedure in a timely manner, but lateral control capability is not significantly affected by an indicated fuel imbalance...

Recorded information

Figure 3 is a graphical display of the fuel tank quantities recorded by the digital flight data recorder (DFDR). The time period covered is from completion of engine start, at 1140 to the time at which the centre tank was completely drained of fuel, at about 1330.

Figure 3: DFDR recorded fuel tank quantities.



A graphical presentation of DFDR data for the fuel quantities recorded in the left and right wing fuel tanks and the centre fuel tanks. The graph covers the recorded data from just after engine start until the centre tank is completely drained of fuel.

Source: ATSB

The data identified that the imbalance was the result of fuel being fed into the right main tank while the engines were being fed fuel from the centre tank. This abnormal condition commenced around the time of the engines start and continued until the centre tank pumps were switched off. The data also identified that, from post-engine start until landing, the fuel panel switch positions were properly set and in accordance with the normal and supplementary procedures.

The maximum differential of 2.6 t occurred at about 1230. At that time, the centre pump low pressure lights illuminated. In response, the flight crew turned the centre tank pumps off and configured the fuel panel to rebalance the fuel between the left and right tanks. The left and right main fuel tanks returned to a balanced condition at 1308, after which the flight crew returned the fuel panel to a normal configuration. The left and right main fuel tanks remained in balance for the remainder of the flight.

Maintenance information

Prior to a flight, the aircraft captain was required to ensure that instruments and equipment necessary for that flight were installed and functioning properly, and that the aircraft was safe for flight. Further, the captain was required to confirm that maintenance actions from the previous flight had been completed and certified as required. The aircraft's technical log was the document for recording defects and maintenance action undertaken on the aircraft.

The captain was required to certify that the aircraft was airworthy, and that no further maintenance was required, through signing the acceptance section of the aircraft's technical log. The VH-EXZ technical log page for the 27 July flight from Auckland to Sydney included the captain's pre-flight inspection signature with a date time just prior to the aircraft's departure.

Not all aircraft components, however, were required to be serviceable before flight. Those components that could be unserviceable, and the processes involved in accepting that unserviceability, was determined through the operator's Minimum Equipment List (MEL).

The Minimum Equipment List

Background

Aircraft are designed to have specific levels of redundancy to achieve a required level of safety. Aircraft manufacturers and the certification authorities have established that the required level of safety is able to be maintained with certain aircraft components being temporarily unserviceable, provided specific conditions are met. The conditions attached to a permitted unserviceability include requirements, such as time limits and/or procedures, to be applied. These permitted unserviceabilities, and their conditions, are published in the aircraft type's Master Minimum Equipment List (MMEL). All items not included within the MMEL are required to be operative, unless they are non-safety-related items.

CASA required an aircraft operator to develop a Minimum Equipment List (MEL). The MEL was to be based on the latest version of the MMEL, but was also required to take into consideration:

- the operator's particular aircraft configuration and equipment
- operating conditions
- routes flown
- any specific legislative and/or regulatory requirements.

The VH-EXZ MEL

The Introduction section in the MEL contained the following guidance:

> Once an aircraft has dispatched, the primary source of information is the Quick Reference Handbook (QRH).

The MEL defined dispatch as:

> The point at which an aircraft first moves under its own power for the purpose of commencing flight.

The MEL also contained a section titled Criteria for Dispatch, which included a subsection titled Managing Defects Occurring after Dispatch and before the Commencement of Take-off that contained the following procedure:

> If after dispatch and before take-off a defect is discovered the following procedure shall be adopted:
>
> a) The associated 'Non-Normal Checklist' shall be consulted / accomplished. Any failure or checklist that does not permit take-off or requires the aircraft to land at the nearest suitable airport will require the flight to be discontinued.
>
> b) The MEL shall then be consulted to determine if dispatch with the item inoperative is available.
>
> i) If the item is not listed in the MEL, or the MEL dispatch remarks or exceptions prohibit dispatch for the proposed type of flight (eg: flight is not conducted in known or forecast icing conditions), then the flight shall be discontinued.

ii) If dispatch is permitted by the MEL, there is no associated (M) procedure and the PIC considers that the unserviceability does not affect the safety of flight having regard for any associated (O) procedures, the weather conditions likely to be encountered enroute, the duration of the flight and the departures, arrivals and approaches expected to be flown, then the flight may continue...

The MEL contained a cross-reference list that matched EICAS messages to their relevant MEL item. That list included the FUEL CONFIG message, which listed three MEL items associated with that message. Two of those MEL items had (M) maintenance procedures attached to them. An (M) annotation identified that a maintenance procedure was required prior to continued operation of the aircraft.

The flight crew reported that, as the aircraft had dispatched the QRH was the primary procedural document. They also assessed that the risk in departing was low.

With regard to the MEL requirements for managing defects after dispatch but prior to take-off, the captain advised not recalling that procedure at the time of the occurrence. The first officer reported having an awareness of the procedure but that it was not consulted in response to the FUEL CONFIG message.

CASA advised that, based on the dispatch criteria and the content of the MEL, the fight crew’s required response to the FUEL CONFIG advisory alert message was to return to the gate and seek maintenance action.

Maintenance action in response to the abnormal fuel system condition

Tasman Cargo Airlines (TCA) held an Australian Air Operators Certificate (AOC) issued by CASA for regular public transport (cargo only) operations. Civil Aviation Safety Regulations (CASR) Part 42 required an AOC holder to be approved by CASA as a continuing airworthiness management organisation (CAMO). The TCA maintenance department held the delegated CAMO responsibility for TCA. Their responsibility included:

- ensuring rectification of defects
- making only approved repairs
- ensuring that each item of operational equipment required by or under the regulations was serviceable and fitted
- if the aircraft was to operate with a defect, that operation was permitted by, among other things, the MEL.

The function of carrying out maintenance on an aircraft required an organisation with specific facilities, trained personnel, and approval to conduct that maintenance under CASR Part 145—that is, it required an approved maintenance organisation (AMO). TCA contracted the provision of maintenance for its aircraft to an AMO external to TCA. That AMO was responsible for line maintenance of TCA aircraft at Auckland and Sydney. The occurrence aircraft was dispatched from Auckland by an AMO engineer, and met in Sydney by an AMO engineer.

The aircraft’s technical log was the source document for recording defects and details of all maintenance carried out on the aircraft. The operating flight crew and authorised ground engineering personnel were required to enter defects, while engineering rectification of that defect was to be recorded by engineering personnel prior to the next flight. The operator also had authorisation for limited pilot performed maintenance, however, this was not relevant for this occurrence.

As the abnormal behaviour of the fuel system was not entered into the aircraft’s technical log, the CAMO reported that they first became aware of the fuel system’s abnormal behaviour on the Tuesday following the occurrence during scheduled interrogation of the aircraft’s Central Maintenance Computer (CMC). Prior to the CAMO becoming aware of the issue, the aircraft had completed a further Auckland to Sydney and return service on the Monday.

In response to the information derived from the CMC, the engineering personnel checked the fuel system, in accordance with the B767 Fault Isolation Manual (FIM) requirements. The abnormal fuel transfer could not be replicated during the ground maintenance inspection. The operator also reported that there were no specific maintenance procedures required following an exceedance of the fuel imbalance limitation.

Boeing advised that the possible causes of the abnormal behaviour were faults in one of three valves. These valves were identified in the FIM procedure for unwanted fuel transfer from the centre tank to a main tank. That FIM procedure identified these valves as being a boost pump bypass valve, a boost pump discharge valve, and a float operated shutoff valve.

PPM—maintenance requirements

The PPM stated that the pilot in command was responsible for the correct completion of all paperwork, including entries into the aircraft's technical log. Post flight, the operating flight crew were required to complete the technical log entries for the flight, including defect reporting where necessary.

The maintenance procedures section also contained requirements on the use of the MEL. This section included the following:

> The MEL contains only those items of airworthiness significance, which may be inoperative prior to dispatch, provided specified limitations and appropriate procedures are observed. Items that are not included in the MEL and related to the airworthiness of the aircraft are required to be operative. Equipment that is not required for safe operation is not listed, e.g. cargo system items that have no airworthiness significance.

Weather information

The Auckland METARs[8] for the period 1130 to 1230 identified that the weather at the aerodrome was fine, the mean wind was north-easterly at 14 kt, visibility was 10 km or greater, the temperature was 17° C and the cloud cover was FEW[9] at 3,100 ft. The METARs were also appended with the trend forecast NOSIG, which identified that no significant changes to the existing conditions were expected for the following three hours.

Related occurrences

A review of the ATSB database did not find any other incidents involving the required use of an MEL post-dispatch/pre take-off. However, the ATSB has previously investigated the following fuel imbalance occurrence that resulted in the aircraft diverting.

ATSB investigation AO-2012-053

On 15 April 2012, a Boeing 737-800 aircraft was being turned around at Gold Coast Airport, Queensland, for a scheduled flight to Melbourne, Victoria. During the turn-around, the fuel system was reconfigured to prevent a fuel imbalance developing because of extended ground operations. That reconfiguration procedure involved the crossfeed valve being selected open. Just prior to departure, procedures required the crossfeed valve to be selected closed. During both operations of the crossfeed valve, the crossfeed valve light indicated normal valve operation.

Following departure from the Gold Coast and during the climb, the flight crew observed that both engines were being supplied fuel from the right fuel tank only. This resulted in a fuel imbalance between the left and right main tanks. In response, the flight crew executed the relevant checklist, which confirmed that no engine fuel leak existed. With centre tank fuel available, the flight crew selected the centre tank fuel pumps on, which resulted in the fuel imbalance stabilising. As the

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8 METAR is a routine weather report of meteorological conditions at an aerodrome.

9 Cloud cover: in aviation, cloud cover is reported using words that denote the extent of the cover – 'few' indicates that up to a quarter of the sky is covered.

flight crew were unable to confirm that fuel from the left main tank could be used once the centre tank pumps were selected off, or that no fuel leak existed, they elected to divert to Brisbane, Queensland.

Subsequent maintenance action identified the cause of the abnormal fuel system operation was a faulty fuel crossfeed valve. The fault prevented the valve from fully closing, resulting in valve leakage.

Safety analysis

Introduction

While VH-EXZ was taxiing for departure from Auckland, a fault in the fuel system resulted in the development of an imbalance in the fuel load between the left and right main tanks. The fault occurred while fuel system was configured for the aircraft's engines to be supplied with fuel from the centre tank. The imbalance became sufficient to trigger the FUEL CONFIG Engine Indication and Crew Alerting Systems (EICAS) advisory alert message.

After some deliberation, the flight crew decided to continue with the departure and address the imbalance airborne. Once airborne, the imbalance continued to increase until, with the centre tank fuel exhausted, the flight crew completed the FUEL CONFIG non-normal checklist to rebalance left and right main tanks.

This analysis will examine the:

- underlying cause of the increasing fuel imbalance
- operational response to the fuel imbalance/FUEL CONFIG alert
- requirements of the Minimum Equipment List (MEL) for equipment failures that occur post-dispatch/pre take-off
- maintenance notification requirements.

The fuel system fault

When the centre tank contains fuel, the fuel system's normal setup is for the centre tank to supply fuel to both engines, with the main (wing) tanks being available to provide fuel should the centre tank fuel pressure fall. This is achieved through the centre tank having higher pump output pressure than the main tank pumps, and all tanks feeding a common manifold through one-way valves (Figure 1). With normal centre tank operation, fuel is not to be pumped from the centre tank into either the left or right main tank.

The effect of the fuel system fault was that fuel was pumped into the right main tank during centre tank operation. The fault did not affect the left main tank, the content of which remained stable. As the right main tank quantity increased while the left remained unchanged, eventually an imbalance resulted that was sufficient to cause the FUEL CONFIG light to activate. This in turn triggered the EICAS FUEL CONFIG advisory alert message.

Maintenance investigation was unable to determine the source of the fault. However, Boeing stated that the likely cause was a fault in one of three fuel system valves.

The departure

During the taxi for departure, the first officer observed the FUEL CONFIG light on the overhead panel briefly flicker. On checking the fuel tank gauges, an imbalance condition was identified, which was marginally around the value necessary to intermittently trigger the FUEL CONFIG advisory alert message.

The first officer rationalised the cause of the imbalance to be extended APU usage and an imbalanced fuel load. While a reasonable assumption, it was incorrect and further examination of available information and discussion between the crew members could have resolved the cause of the imbalance at this stage. Departure procedures and clearance to enter the runway for departure followed, by which time the abnormal fuel system behaviour had increased the imbalance sufficiently to activate the FUEL CONFIG advisory alert message.

The flight crew's response to the FUEL CONFIG alert

The activation of an EICAS alert message required the flight crew to initiate the associated non-normal checklist. The EICAS prioritised alerts in a manner that indicated the safety impact of the triggering fault or condition. In the hierarchy of alerts, the advisory alert was the lowest priority. It identified a need for crew awareness, and that corrective action may be required.

The checklist actions in response to an EICAS FUEL CONFIG advisory alert message were found in the Quick Reference Handbook (QRH). The FUEL CONFIG checklist identified that a possible cause of an imbalance was a fuel leak, and in its first item it required determination of whether a fuel leak existed through the conduct of a specific procedure. The flight crew performed this check.

The remainder of checklist required adjustment of the fuel panel to bring the fuel tanks back into balance. As the alert was of a low priority, the flight crew conferred and agreed to depart and address the imbalance condition airborne. The low priority of the alert and the impending departure, however, appears to have influenced investigation of the cause of the imbalance and the fault indications that were present.

The Minimum Equipment List procedure

The actions required of the flight crew in response to the FUEL CONFIG advisory alert message before departure were not limited to the conduct of the relevant non-normal checklist. The operator's Minimum Equipment List (MEL) for VH-EXZ also contained a procedure required to be conducted by the flight crew in the event of equipment failure occurring post-dispatch but before take-off.

That procedure first required completion of the relevant QRH checklist. If that checklist did not require a return for maintenance action, then the MEL item for that equipment failure was to be examined. If the requisite MEL relief required maintenance action, then the aircraft was to be returned for that action. There were also other safety related considerations to be completed that also required return for maintenance.

On this occasion the captain did not recall the MEL procedure relating to the management of defects that occurred between dispatch and take-off. While the first officer did report an awareness of this procedure, both flight crew were influenced by the QRH being the primary document for response to the alert. After applying the required QRH checklist to the point where the procedure called for changing the aircraft's fuel system configuration, they decided to take-off.

That action was probably the result of a common belief that the risk was low enough for the flight to proceed. That assessment could be supported by the advisory status of the alert message as well as Boeing's guidance regarding fuel imbalance and on delaying balancing during critical phases of flight.

However, non-compliance with the MEL procedure meant that a risk control designed to prevent the aircraft departing with faulty equipment was not applied.

Departure decision with fuel imbalance

The aircraft departed Auckland with a fuel system that was operating in an abnormal manner as a result of a fault. This raised the risk that further fault could affect the safety of the flight. The departure was also made without the required MEL consideration.

Flight crew's actions airborne

The flight crew did not identify the abnormal behaviour of the fuel system until after the aircraft had departed Auckland and was established in the climb. Having identified that fuel was being transferred into the right main tank and was causing an increasing imbalance, the flight crew decided to continue to monitor the fuel system and delay rebalancing the fuel distribution until after the fuel in the centre tank was depleted. This decision was based on:

- the rebalancing procedure requiring the centre tank pumps to be switched off, which in turn would result in the FUEL CONFIG advisory alert message
- Boeing guidance on fuel imbalance, which indicated that the fuel imbalance alert was a compromise between minimising crew attention to rebalancing and minimising excess fuel usage due to trim considerations
- the aircraft’s trim indicating that the aircraft was not affected by the imbalance condition
- the low priority of the FUEL CONFIG advisory alert message.

While these considerations indicated minimal risk from delaying rebalancing, the Policy and Procedures Manual required the flight crew to observe the Aircraft Flight Manual fuel imbalance limitation. This limitation was significantly exceeded because of the delay in rebalancing. Further, while the flight crew exhibited a level of concern about the system’s operation, as demonstrated by the captain’s continued check for a fuel leak, they did not determine whether the fuel system fault affected access to all fuel in the tanks. As a result, the flight crew’s actions once airborne presented an increased risk to the aircraft's operation.

Maintenance notification requirements

All faults and abnormal system behaviour were required to be reported in the aircraft’s technical log to ensure corrective maintenance action was completed. The responsibility for this rested with the aircraft’s captain. While the captain verbally notified the maintenance engineers in Sydney and Auckland about the abnormal behaviour, the engineering system’s structure and the absence of the technical log entry resulted in a significant delay in maintenance action to identify and correct the fault.

Further, that delay resulted in the aircraft being dispatched for an Auckland to Sydney and return service without corrective maintenance action being undertaken. While centre tank fuel was not taken on that flight, the delay in maintenance action directly affected the likelihood of the maintenance being able to identify and correct the fault that caused the imbalance to occur.

Findings

ATSB investigation report findings focus on safety factors (that is, events and conditions that increase risk). Safety factors include 'contributing factors' and 'other factors that increased risk' (that is, factors that did not meet the definition of a contributing factor for this occurrence but were still considered important to include in the report for the purpose of increasing awareness and enhancing safety). In addition 'other findings' may be included to provide important information about topics other than safety factors.

These findings should not be read as apportioning blame or liability to any particular organisation or individual.

From the evidence available, the following findings are made with respect to the fuel imbalance involving the Boeing 767-3JHF at Auckland Airport, New Zealand on 27 July 2019.

Contributing factors

- A fault in the fuel system, likely caused by the malfunctioning of one of three fuel system valves, resulted in fuel inadvertently being fed into the right main tank and a gradually increasing fuel imbalance between the left and right main tanks. As the aircraft approached the departure runway, this abnormal fuel system behaviour triggered the FUEL CONFIG caution light, and the associated Engine Indication and Crew Alerting System advisory alert message.
- Having considered the likelihood of a fuel leak and the low priority of the alert, the flight crew decided to address the imbalance once airborne. However, they did not consider the Minimum Equipment List procedural requirements to return to the line for maintenance action.

Other factors that increased risk

- The flight crew became aware of the abnormal fuel system operation shortly after becoming airborne but delayed completion of the associated non-normal checklist. That resulted in continued increase in the fuel imbalance beyond the allowable limit, unnecessarily elevating the safety risk.
- Contrary to the requirements of the operator's policy and procedures manual, the abnormal behaviour of the fuel system was not entered into the aircraft's technical fault log. This resulted in a delay to maintenance corrective action until after a further two sectors had been flown by the aircraft, and probably impacted identification of the underlying fault.

Safety action

Safety action not associated with an identified safety issue

Whether or not the ATSB identifies safety issues in the course of an investigation, relevant organisations may proactively initiate safety action in order to reduce their safety risk. The ATSB has been advised of the following proactive safety action in response to this occurrence.

Additional safety action by Tasman Cargo Airlines

On 22 March 2021, Tasman Cargo Airlines advised the ATSB that an amendment to the Minimum Equipment List (MEL) had been drafted to include clarification as to crew actions in the event of an Engine Indication and Crew Alerting System (EICAS) message between off blocks and take-off.

This amendment will be situated in the early part of the MEL Introduction section. Tasman Cargo Airlines will also alert flight crew to the procedural requirement through notification of the MEL amendment.

General details

Occurrence details

Date and time:	26 July 2019 – 1200 NZST	
Occurrence category:	Incident	
Primary occurrence type:	Fuel systems	
Location:	Auckland International Airport, New Zealand	
	Latitude: 37º 00.480' S	Longitude: 174º 47.502' E

Aircraft details

Manufacturer and model:	The Boeing Company 767	
Registration:	2012	
Operator:	Tasman Cargo Airlines	
Serial number:	37808	
Type of operation:	Air Transport High Capacity – Freight	
Departure:	Auckland, New Zealand	
Destination:	Sydney, New South Wales	
Persons on board:	Crew – 2	Passengers – 0
Injuries:	Crew – 0	Passengers – 0
Aircraft damage:	None	

Sources and submissions

Sources of information

The sources of information during the investigation included:

- the flight crew of VH-EXZ
- Tasman Cargo Airlines
- the Civil Aviation Safety Authority
- The Boeing Company
- recorded data from the aircraft's Digital Flight Data Recorder.

References

Bolstad, C. A., and Endsley, M. R. (1999). Shared mental models and shared displays: An empirical evaluation of team performance. Proceedings of the 43rd Annual Meeting of the Human Factors and Ergonomics Society. Santa Monica, CA: Human Factors and Ergonomics Society.

Endsley, M. R., and Jones, W. M. (1997). Situation awareness, information dominance, and information warfare (AL/CF-TR-1997-0156). Wright-Patterson AFB, OH: United States Air Force Armstrong Laboratory.

Submissions

Under section 26 of the *Transport Safety Investigation Act 2003*, the ATSB may provide a draft report, on a confidential basis, to any person whom the ATSB considers appropriate. That section allows a person receiving a draft report to make submissions to the ATSB about the draft report.

A draft of this report was provided to the following directly involved parties:

- the flight crew of VH-EXZ
- Tasman Cargo Airlines
- the Civil Aviation Safety Authority
- The Boeing Company
- the National Transport Safety Board.

Submissions were received from:

- the flight crew of VH-EXZ
- Tasman Cargo Airlines
- the Civil Aviation Safety Authority.

The submissions were reviewed and, where considered appropriate, the text of the report was amended accordingly.

Australian Transport Safety Bureau

About the ATSB

The ATSB is an independent Commonwealth Government statutory agency. It is governed by a Commission and is entirely separate from transport regulators, policy makers and service providers.

The ATSB's purpose is to improve the safety of, and public confidence in, aviation, rail and marine transport through:

- independent investigation of transport accidents and other safety occurrences
- safety data recording, analysis and research
- fostering safety awareness, knowledge and action.

The ATSB is responsible for investigating accidents and other transport safety matters involving civil aviation, marine and rail operations in Australia, as well as participating in overseas investigations involving Australian-registered aircraft and ships. It prioritises investigations that have the potential to deliver the greatest public benefit through improvements to transport safety.

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

Purpose of safety investigations

The objective of a safety investigation is to enhance transport safety. This is done through:

- identifying safety issues and facilitating safety action to address those issues
- providing information about occurrences and their associated safety factors to facilitate learning within the transport industry.

It is not a function of the ATSB to apportion blame or provide a means for determining liability. At the same time, 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. The ATSB does not investigate for the purpose of taking administrative, regulatory or criminal action.

Terminology

An explanation of terminology used in ATSB investigation reports is available on the ATSB website. This includes terms such as occurrence, contributing factor, other factor that increased risk, and safety issue.