Australian Government
Australian Transport Safety Bureau

ATSB TRANSPORT SAFETY INVESTIGATION REPORT
Aviation Occurrence Investigation – 200605274
Final

Engine in-flight shutdown
185 km south of Karratha, WA
6 September 2006
VH-NXI
Boeing Co 717-200

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Abstract

On 6 September 2006, a Boeing Co 717-200 (717) aircraft, registered VH-NXI, departed Perth, WA on a scheduled passenger service to Karratha. Approximately 100 NM (185 km) from Karratha, there was an automated thrust reduction and the aircraft commenced the descent into Karratha.

Shortly after leaving the top of descent, the flight crew observed that the right engine had failed. During the completion of the relevant non-normal checklist items, the crew noticed that the main fuel switch for the right engine was selected to OFF. The engine failure checklist was carried out and a successful restart made as the aircraft continued to Karratha.

An examination of the throttle module and main fuel switches by the aircraft operator found no fault with their operation.

As a result of this incident, the aircraft operator issued a Safety Alert to all of its 717 operating crew advising of the possibility of selecting the aircraft's main fuel switches to ON without their correctly engaging the locking detent. That alert also warned flight crew of the possibility of inadvertent in-flight selection of the switches to OFF by catching wristbands or long sleeve shirt cuffs. In addition, flight crew were advised to not pass technical manuals or other similar items across the throttle quadrant in the vicinity of the main fuel switches.

The operator is evaluating the possible fitment of a physical guard to protect the main fuel switches against their inadvertent unlock from the ON position.

THE AUSTRALIAN TRANSPORT SAFETY BUREAU

The Australian Transport Safety Bureau (ATSB) is an operationally independent multi-modal Bureau within the Australian Government Department of Transport and Regional Services. 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

Sequence of events

At 1056 Western Standard Time[1] on 6 September 2006, a Boeing Co 717-200 (717) aircraft, registered VH-NXI, with six crew and 97 passengers on board departed Perth, WA on a scheduled passenger service to Karratha. The copilot was the pilot flying for the flight.

At 1212, when approximately 100 NM (185 km) from Karratha, an automated thrust reduction resulted in the aircraft commencing its descent from the cruise altitude of Flight Level[2] (FL) 330. The flight crew reported that, shortly after leaving FL330, they observed the following warning indications and control movement:

- a momentary amber coloured 'X' over the right engine's N1[3] indicator display
- on the aircraft's Engine and Alert Display:
  - an alert of GEN R OFF (right engine generator off)
  - an AIR R warning (right engine pneumatic pressure)
  - a HYD R warning (right engine hydraulic pressure)
- significant advancement of the aircraft's autothrottles[4].

In addition, the aircraft's multifunction display and control unit automatically scrolled to the ENGINE OUT display page.

After identifying the non-normal situation, the pilot in command (PIC) assumed the pilot flying duties from the copilot. The flight crew confirmed the failure of the right engine and actioned the Engine Failure Inflight Checklist that was contained in the in-cockpit quick reference handbook (QRH). That checklist included the requirement to select the throttle for the failed engine to idle. During that throttle selection, the crew noticed that the main fuel switch for the right engine was selected to OFF, and realised that that switch position was consistent with an in-flight shutdown (IFSD).

The flight crew stated that, after confirming that neither pilot had selected the fuel switch to OFF, they completed the Engine Failure and Restart Inflight Checklists. The engine was restarted as the aircraft descended through FL160. The engine

1 The 24-hour clock is used in this report to describe the local time of day, Western Standard Time (WST), as particular events occurred. Western Standard Time was Coordinated Universal Time (UTC) + 8 hours.

2 Operating altitudes above 10,000 ft above mean sea level (AMSL) are referred to as flight levels. FL330 equates to 33,000 ft AMSL.

3 Engine fan or low pressure compressor speed.

4 Engine power control system that automatically varies thrust in order to maintain relevant flight parameters. In this case, compensating for the run down of the right engine by increasing the thrust provided by the left engine.

stabilised at idle thrust and all of the warning indications extinguished, with the exception of the HYD indication.

The PIC continued the descent to FL110 while the HYD checklist was actioned. That action restored the right engine hydraulic system pressure to normal.

The flight crew reported that, as a result of the rectification of the non-normal situation, and the resumption of normal operations, the PIC returned the pilot flying duties to the copilot, who continued the flight to Karratha.

Company maintenance inspection

The operator's maintenance personnel examined the aircraft's throttle module[5] and main fuel switches, but could find no fault with their operation. That examination did, however, note some wear on the locking shoulders of the right fuel switch detents. The operator's maintenance examination suggested that that wear would allow 'easier egress [of the switch] from the detent position'. As a precaution, the operator replaced the throttle module prior to returning the aircraft to flight operations.

Review of pertinent flight crew actions during the flight

The flight crew stated that the pre-flight preparations, start and subsequent takeoff were routine. The PIC stated that the start was performed in accordance with the Flight Crew Operating Manual (FCOM), including verification of the engagement of the right main fuel switch detent in the ON position.

The manually-flown departure from Perth was in order for the copilot to prepare for an upcoming simulator check flight. As a result of moderate turbulence in the Perth area, the copilot elected to use a higher-than-normal acceleration altitude[6] of 3,500 ft. That increased acceleration altitude was permitted in accordance with the operator's standard operating procedures.

The flight crew advised of the following in-flight activities during which there may have been the potential to have inadvertently activated the right main fuel switch:

- **Change of radio frequency departing Perth.** When climbing through 3,000 ft, the crew requested and received approval from air traffic control (ATC) to transfer to the Perth departures frequency. The flight crew stated that, during that change of frequency, their hands and wrists did not come within an estimated 20 mm of the fuel switches.
- **Retraction of the wing slats[7] climbing through 6,000 ft.** In order to retract the aircraft's wing slats, the copilot removed his hands from the throttles at or when climbing through about 6,000ft.

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5 The 717 throttle quadrant is a modular design to allow its quick-disconnect and removal. The main fuel switches are mounted on the rear face, and are a part of, this module.

6 Acceleration Altitude. A pause in an aircraft's climb profile, during which the aircraft's speed is increased, prior to resuming the normal climb.

7 Movable portion of the leading edge of an aerofoil that, when activated, forms a slot ahead of the main surface of the aerofoil and delays the aerodynamic stall at high angles of attack.

The flight crew felt that, although the copilot was flying the aircraft manually during those activities, and was wearing a heavy watch with a loose wrist band that hung quite close to the fuel switches, that had not been a factor. However, the flight crew considered that, had the fuel switch been inadvertently knocked at that time, there was the potential for it to have remained unnoticed as a result of the higher workload associated with the manual departure, combined with the effects of the in-flight turbulence.

After retracting the slats in the climb, the aircraft was controlled by its automated systems, and the flight proceeded uneventfully through the remainder of the climb and the cruise until the commencement of the descent into Karratha. The flight crew reported that, during that time, they carried out ancillary tasks, such as the incorporation of aircraft technical manual amendments, and discussed the copilot's upcoming check flight.

At or close to position ROSEY[8], ATC cleared the aircraft for descent into Karratha and the copilot requested the PIC to input the relevant flight data for the descent and approach into the aircraft's flight management system. During that programming, the crew noted an automatic reduction in thrust, which coincided with the planned top of descent (TOPD) and commencement of the descent.

The flight crew were adamant that they had not contacted the right main fuel switch, or been required to manipulate any adjacent equipment, for at least ten minutes prior to TOPD. They conceded that it was possible that the switch may have been inadvertently moved from its detent at some point prior to that time, and remained unnoticed.

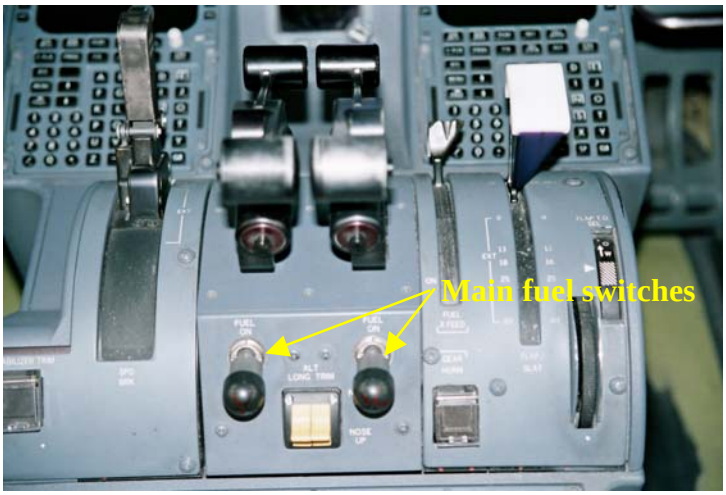
Aircraft information

Boeing 717 fuel switch

In the 717, LEFT and RIGHT main fuel switches allow the flow of fuel to their respective engine. The switches are a lever lock toggle design, and are located on the rear face of the throttle quadrant that is located between the pilots' seats (Figure 1).

8 A compulsory position reporting point for all instrument flight rules aircraft, located 143 NM (265 km) south of Karratha.

Figure 1: Boeing 717 throttle module (fuel switches indicated)

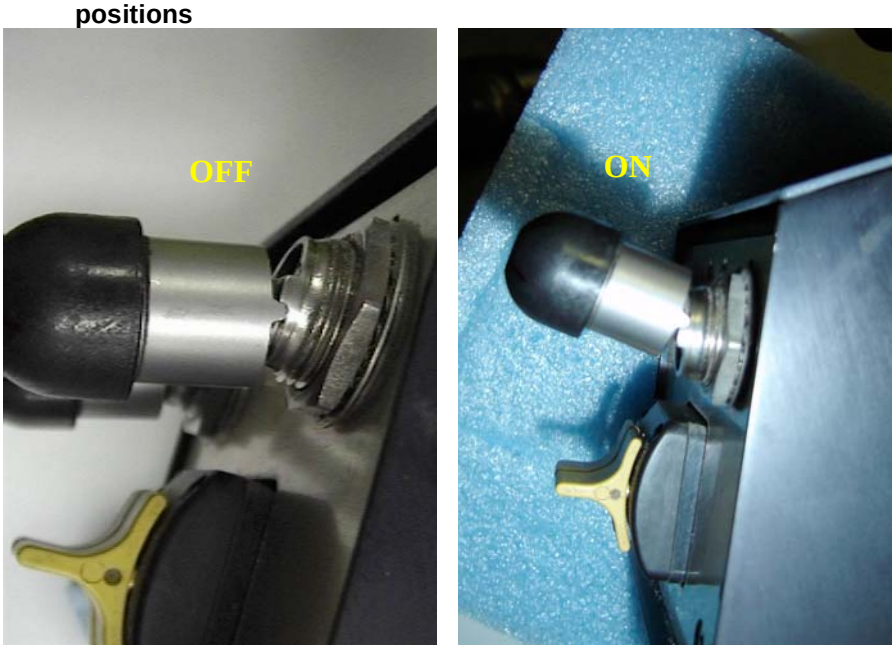


The main fuel switches command the opening and closing of each engine's high pressure shut off valve (HPSOV) within the fuel control system. They have ultimate control authority over their respective HPSOV, and therefore corresponding engine fuel supply, in all instances except ground start abort. In that case, the respective switch's action is overridden by the electronic engine control (EEC), which will initiate an engine shutdown by commanding the closure of the HPSOV, irrespective of the position of the affected fuel switch.

Fuel switch selection to the OFF and ON positions

An indication of the main fuel switches when selected to the OFF and ON detents is at Figure 2.

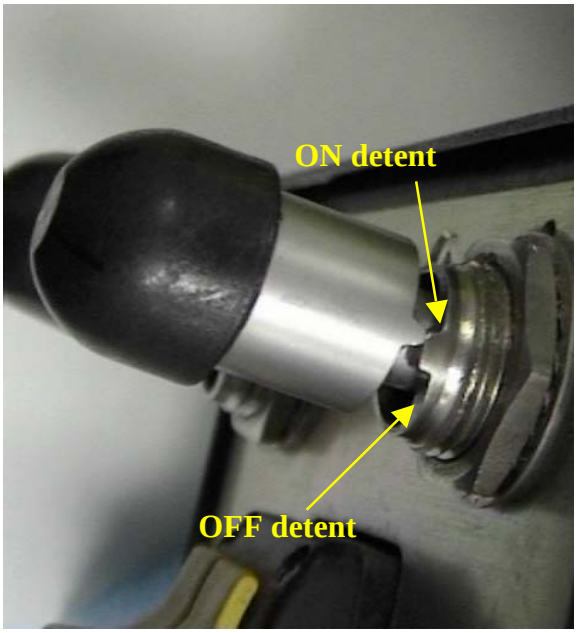
Figure 2: Fuel switch in the locked OFF (left), and locked ON (right) detent positions



However, the operator's examination of this incident determined that the aircraft's right main fuel switch could be inadvertently selected to an intermediate position,

including as a result of its being caught by a pilot's wristwatch band (Figure 3). That was, the switch could be moved from the locked ON detent to an unlocked, but still ON, position The operator also identified that the switches may be vulnerable to being 'snagged' or knocked by flight deck equipment or publications such as ring binders.

Figure 3: Fuel switch in an out of detent (unlocked), ON position



Aircraft manufacturer comment on the 717 main fuel switches

The aircraft manufacturer advised that the lever lock design of the fuel switch that was installed in the 717 required a force of about 3lbs (1.4kg) to lift the lever lock from its detent. In addition, the manufacturer commented that electrical contact to the ON state occurred as the lever lock was moved out of the OFF detent and beyond about 10 degrees past the vertical axis.

One previous incidence of an inadvertent IFSD in a 717 aircraft was recorded by the manufacturer. That inadvertent shutdown occurred on 5 May 2000, and was attributed to the PIC accidentally selecting the affected main fuel switch to OFF while selecting the aircraft's fuel cross-feed lever to the OPEN position.

Following that May 2000 incident, the airframe manufacturer conducted an investigation that included an examination of the properties of the lever lock switch that was being used in production 717 aircraft. No anomalies were found, and the force required to actuate the production switch was in accordance with the stipulated supplier specifications. A Flight Operations Bulletin was issued immediately after the incident to highlight the event to all operators of the 717, and to direct crews to confirm that main fuel switches were correctly latched in the ON position by 'jiggling' and pushing down on the switch after its selection. In addition, the aircraft manufacturer included a section on the correct use of the main fuel switches in the 717 training syllabus, and the 717 Automatic and Manual Engine Start Procedures in Volume II of the FCOM were amended to introduce the fuel switch 'jiggle' check.

During this investigation, the Australian Transport Safety Bureau (ATSB) queried the ergonomics of the 717 main fuel switches and the risk of the switches being inadvertently moved during normal operations. In response, the manufacturer stated that:

> With respect to a possible ergonomic concern, know that the B717's Throttle Control Module (TCM) design requirements were to duplicate the throttle/switch location as close as possible to predecessor models (MD-90). The geometry of this relationship was reviewed for the MD-90 centre pedestal's affected area and similar areas of the B717's TCM. Results indicated that with the throttles at the idle position, the difference in height (Z-dimension) or forward/aft (longitudinal, Y-dimension) spacing between the MD-90 and the B717 fuel switch to throttle knobs is less than about 0.60 inch (1.52cm), respectively. Further, we have had no reports of engine IFSD's due to the identical fuel switch being inadvertently turned off from any MD-90 operator.

and that:

> [the main fuel switch] is used in Boeing-Long Beach Division models having engines controlled by electronic means (FADEC[9]/Electronic Engine Control (EEC)). These include the MD-11, MD-90 and B717 models. The baseline switch is also used in Boeing-PS FADEC models.

There was no data available on the effect of wear on proper detent locking associated with prolonged in-service operation of the switch mechanism.

Quick relight function

The 717 includes an engine 'Quick Relight' capability, which is enabled when the aircraft is in flight, and the engine N2[10] speed is greater than idle. That capability is via the EEC logic, which monitors main fuel switch movement in order to relight an engine should a fuel switch be inadvertently moved by a crew to OFF, before being quickly reselected to ON. When activated, the Quick Relight function automatically initiates an engine relight by activating the affected engine's igniters, and scheduling fuel flow to that engine.

The EEC relight logic has effect when a main fuel switch is moved to OFF, before being re-set to ON within 20 seconds of the initial movement to OFF. In that case, the EEC logic provides for a 30-second period in which the affected engine's igniters are activated. The result is that the engine will be restarted, and will return to the thrust set by the throttle lever angle.

If the 20-second period allowed for the reselection of the affected main fuel switch to ON elapses without its reselection, then a normal engine shutdown will result.

Advice from the aircraft manufacturer confirmed that any uncorrected movement of the right main fuel switch to OFF must have occurred at a maximum of 20 seconds prior to the in-flight shutdown.

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9 FADEC - Full Authority Digital Engine (or Electronic) Control.

10 Engine high pressure compressor speed.

Recorded information

The aircraft was equipped with a Honeywell Intl. Inc. Solid State Flight Data Recorder.

The recorded data for the flight was downloaded and examined by the ATSB. That examination showed that the engine parameters were normal and matched for both engines until a position and time that coincided with the TOPD. At that time, the right main fuel switch position changed to OFF, and the right engine shut down.

Additional information

Pilot fatigue

During the investigation, the PIC suggested that his level of fatigue may have contributed to the development of the occurrence. The usual effects of fatigue can include increased reaction time, reduced attention and diminished memory. Other indicators of fatigue include poor selective attention choices and poor decision making.

A history of the PIC's duty times, based on the sign-on and sign-off times provided by the pilot for the three weeks prior to the incident was examined by the investigation. That included the conduct of a fatigue analysis on that data using the Fatigue Audit InterDyne (FAID) methodology. FAID predicts an individual's work-related fatigue level based on the time of day of duty and breaks, duration of duty and breaks, duty history in the preceding seven days, and the biological limits on recovery sleep.

The FAID analysis indicated that, at the time of the occurrence, the predicted fatigue for the PIC was in the standard range. That was, below the fatigue level typically experienced at the end of a working week by a normal non-shift worker. During each duty period examined, the FAID analysis never exceeded the bottom of the moderate range (with peaks typically during early morning shifts), which was well below any level that could be expected to cause any performance impairment.

ANALYSIS

The in-flight shutdown of the right engine as the aircraft commenced its descent into Karratha was consistent with the recorded movement of the right main fuel switch to OFF at that time.

In the absence of any conscious action by the flight crew to select the right main fuel switch to OFF, its movement can only have been as a combination of:

- its initially being at some position between where electrical contact to the ON state had occurred and the locked ON position
- the switch vibrating or being unintentionally moved or knocked from that intermediate position at the top of descent (TOPD) for the approach into Karratha.

The investigation considered the possible mechanisms for the right main fuel switch to have been unlocked prior to its movement to OFF. Those mechanisms included that the switch was in fact not properly locked in the ON position as part of the start procedure, or that the unlock occurred sometime between the completion of the start procedure and the TOPD.

The indication by the pilot in command of the selection of the main fuel switches to ON in accordance with the Flight Crew Operating Manual (FCOM) during the start procedure suggested that the unlock of the right main fuel switch occurred during the flight. Whether that had been as a result of its being 'snagged' by the flight crew's clothing or watch, or as a result of being knocked by a document binder or other object, could not be determined.

While the aircraft manufacturer's FCOM defence of 'jiggling' the main fuel switches addressed the need to ensure that they were locked ON, it did not address the potential for the switches to become unlocked during flight. Although unable to be quantified, the wear found on the right main fuel switch in this case may have increased the likelihood for that to have occurred. The short haul, high frequency shuttle nature of the 717 operation has the potential to increase the wear rate of the main fuel switches which, together with their relatively exposed position on the rear face of the throttle quadrant, could increase the risk of future unintentional in-flight engine shutdowns.

The usual effects of fatigue, including increased reaction times, reduced attention and diminished memory were unlikely to have contributed to the fuel switch being moved, or to have reduced the chance of its position being noticed by the pilots. Other indications of fatigue, like poor selective attention choices and poor decision making, did not appear to be present during the engine shutdown and subsequent start-up procedures. That, and the results of the fatigue analysis, showed that it was very unlikely that fatigue contributed to the development of the occurrence.

FINDINGS

Contributing safety factor

- The right main fuel switch was moved to OFF at the commencement of the descent into Karratha. The means for that switch movement could not be determined.

Other safety factor

- Electrical contact of the main fuel switches to the ON state is possible when the switches are not locked in the ON detent.

Other key findings

- The ‘Quick Relight’ function was not a factor in this occurrence.
- It was very unlikely that fatigue was a factor in this occurrence.

SAFETY ACTION

The following discussion details the safety actions that were communicated to the Australian Transport Safety Bureau (ATSB) during the investigation.

Operator

The aircraft operator issued a Safety Alert to all of its 717 operating crew advising of the possibility of selecting the aircraft's main fuel switches to ON without their correctly engaging the locking detent. That alert also warned flight crew of the possibility of the inadvertent in-flight selection of the switches to OFF by catching wristbands or long sleeve shirt cuffs. In addition, flight crew were advised to not pass technical manuals or other similar items across the throttle quadrant in the vicinity of the main fuel switches.

The operator is evaluating the possible fitment of a physical guard to protect the main fuel switches against their inadvertent unlock from the ON position.