Australian Government

Australian Transport Safety Bureau

ATSB TRANSPORT SAFETY REPORT

Aviation Occurrence Investigation – AO-2007-034

Final

Fuel system event
Near Rockhampton aerodrome, Qld
13 Aug 2007
VH-VBR
Boeing Company 737-7BX

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Abstract

On 13 August 2007, a Boeing 737-700 aircraft, registered VH-VBR, was operating on a scheduled flight from Brisbane to Hamilton Island, Qld. On reaching cruise altitude, the flight crew became aware of a fuel imbalance situation due to fuel loss from the number-2 (right) engine. At 1311 Eastern Standard Time and approximately 148 km SE of Rockhampton, Qld, the crew conducted an in-flight shut down of the right engine. The aircraft was subsequently diverted to Rockhampton where a single-engine approach and landing was completed without further incident.

Examination identified the leak as being from the main fuel return pipe where it connected into the oil/fuel heat exchanger. The pipe connection was of flanged plate design, held in position by four bolts tightened into threaded inserts on the oil/fuel heat exchanger body. The threaded inserts had failed, pulling free of the heat exchanger body.

The investigation found that the failure of the inserts was the result of over tightening that had occurred during previous maintenance. The oil/fuel heat exchanger was subject to two different modification states, each requiring different fuel return pipe bolt torque values.

As a result of this occurrence, the aircraft operator notified the subsequent maintenance provider of the incident and received assurance that their process, procedures and oversight were adequate to prevent a recurrence.

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 organisations.

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

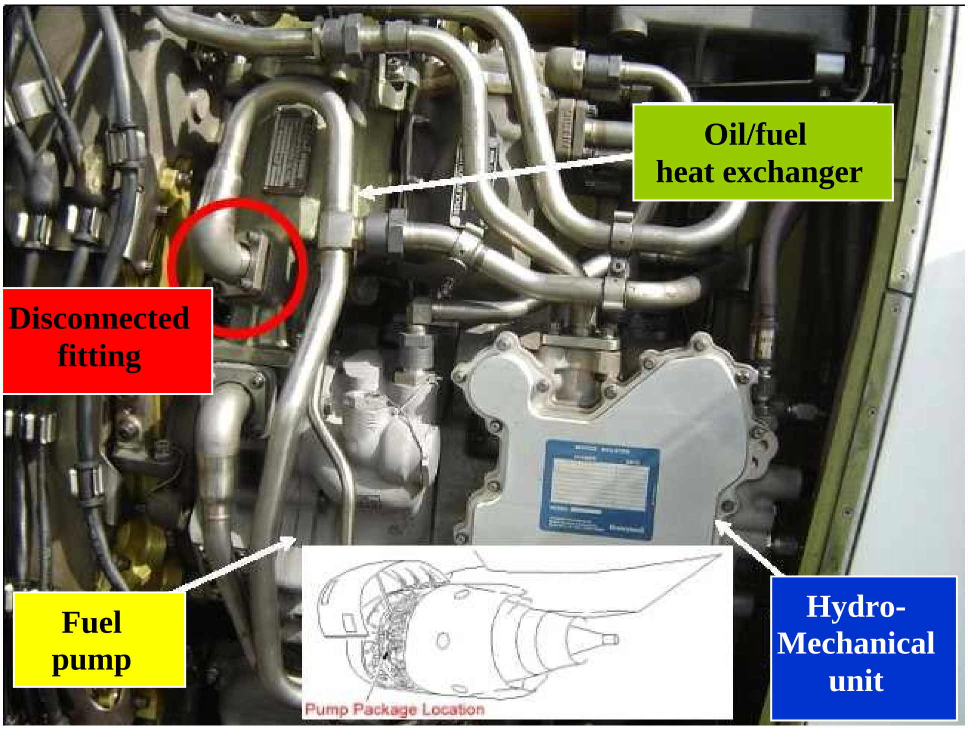
The information presented below, including any analysis of that information, was prepared principally from information supplied to the Bureau.

Sequence of events

On 13 August 2007, a Boeing Company 737-7BX aircraft, registered VH-VBR, was being operated on a scheduled passenger flight from Brisbane to Hamilton Island, Qld. On reaching cruise altitude, the flight crew became aware of a fuel imbalance situation due to fuel loss from the number-2 (right) engine. At 1311 Eastern Standard Time[1] and approximately 148 km south-east of Rockhampton, Qld, the crew conducted an in-flight shut down (IFSD) of the right engine. The aircraft was subsequently diverted to Rockhampton where a single-engine approach and landing was conducted.

A subsequent examination of the number-2 engine during an engine ground run revealed that fuel was leaking from the engine 'fuel pump package' area. The fuel pump package incorporated the fuel pump, the hydro-mechanical unit (HMU) and an oil/fuel heat exchanger. The leak was identified as being from the main fuel return pipe where it connected into the oil/fuel heat exchanger. The pipe connection had partially disconnected from the oil/fuel heat exchanger (Figure 1).

Figure 1: Fuel return pipe to oil/fuel heat exchanger fitting

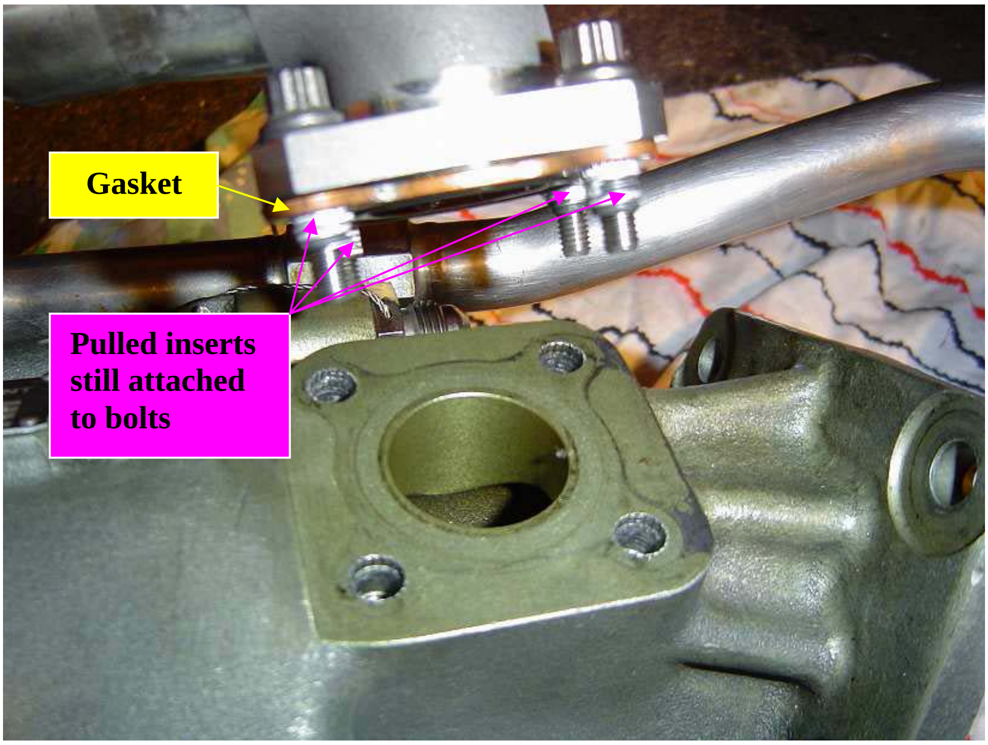


1 The 24-hour clock is used in this report to describe the local time of day, Eastern Standard Time (EST), as particular events occurred. Eastern Standard Time was Coordinated Universal Time (UTC) + 10 hours.

The pipe connection was of a flanged plate design, secured by four bolts. The connection was sealed by an aluminium gasket containing a rubber seal between the pipe flange and the oil/fuel heat exchanger.

All four of the pipe attachment bolts were accounted for, being tightly connected to the fuel pipe flange plate. However, the corresponding steel-threaded inserts within the heat exchanger had failed and pulled free of the heat exchanger body, and were still attached to the bolts (Figure 2).

Figure 2: Fuel pipe flange plate and gasket showing pulled inserts



Oil/fuel heat exchanger

The oil/fuel heat exchanger fitted to the engine was a SECAN (F0569), part number 11-841193-2, serial number YY081139-B. It had been installed on the engine since manufacture and had not undergone any modification, repair or overhaul since new.

As a result of a number of in-service failures of the fuel return pipes experienced by operators, the oil/fuel heat exchangers were subject to several modification requirements.

The engine manufacturer issued service bulletin CFM56 SB79-0023, issued 30 April 2004, requiring the replacement of pre-modified (-2) heat exchangers with the modified (-4) items at engine overhaul. Once replaced with the (-4) item, the use of flat washers under the attachment bolt heads on the fuel return pipe, was no longer required. To implement that change, another service bulletin CFM56 SB72-0468 was issued on 6 July 2005.

The fuel system component manufacturer, SECAN/Honeywell, issued service bulletin SB11-841193-79-02, on 20 December 2006. That service bulletin required the replacement of the threaded inserts on the oil/fuel heat exchanger with key locked inserts at the next engine shop visit.

The right engine on VH-VBR had not undergone a shop visit since the issue of the service bulletin on 20 December 2006. As a result, the oil/fuel heat exchanger had not yet been modified and was a pre-SB11-841193-79-02 item, with the part number ending in -2.

Previous fuel leak

The aircraft operator conducted an internal investigation into the incident. The operator's investigation report stated that, on 11 August 2007, 2 days and three flights prior to the incident, during a routine walk-around check of the aircraft at Sydney Airport, an excessive amount of fuel was observed leaking from the number-2 engine fuel drain. On that occasion, the leak was traced to the engine-driven fuel pump, which was then replaced. To facilitate the replacement of the fuel pump, the fuel pump package was removed. Once removed from the aircraft, the components were separated from the fuel pump package for the fitment of the replacement pump.

The removal of the fuel pump package from the aircraft and separation of the components, were conducted that evening. The task was completed the following day, 12 August 2007, following the arrival of the replacement fuel pump. The maintenance crew responsible for completion of the rectification task the next day, consisted of one aircraft maintenance engineer (AME) and one licensed aircraft maintenance engineer (LAME).

The task was certified by the LAME in the aircraft's technical log book as being carried out in accordance with the aircraft maintenance manual (AMM) task 73-11-01 and the aircraft was subsequently released back into service.

Installation of main fuel-return pipe

The installation of the main fuel-return pipe was carried out under AMM task 73-11-01-400-801-FOO – *Fuel Pump Package Installation*. Subtask 73-11-01-420-012-FOO, steps 11 (m) & (n), provided the torque settings for the attachment bolts (Appendix A). The four bolts were required to be tightened to the required torque diagonally to prevent distortion of the gasket.

As this installation was a pre-CFM56-SB72-0023 or pre-CFM56 SB72-0468 modified configuration, the bolts were required to be tightened to a torque value of 49 to 53 pounds-inches (5.5 to 6.0 Newton-meters). Post-CFM56-SB72-0023 or post-CFM56 SB72-0468 modified installations required a final tightening of the bolts to a maximum torque of 42.2 to 60 pound-inches (4.77 to 6.78 Newton-meters). The AMM task contained notes specifying the correct torque values for both the pre- and post-modification installations. The AME involved in the task, reported that he had carried out the fuel pipe fitment and had tightened the bolts in a diagonal sequence as required by the AMM to a final torque value of 60 pound-inches. He reported that the gasket was in good condition with no signs of deterioration of the rubber seal. He confirmed there did not appear to be any defects with the oil/fuel heat exchanger flange surface or inserts. The AME and another LAME carried out the leak check inspection of the engine during the subsequent ground run and identified a small fuel leak from another pipe fitted to the top of the HMU. No leaks from the oil/fuel heat exchanger or the fuel pipe attachment were evident. The AME advised that he was not aware of the SB notes included in the AMM installation task, specifying the different torque values.

The LAME working with the AME was involved with another task at the time the fuel pipe to oil/fuel heat exchanger was connected, so did not see the condition of the gasket or inserts prior to assembly, nor did he observe the tightening of the attachment bolts.

The operator conducted a subsequent calibration check of the torque wrench used by the AME and determined it was reading approximately 1 per cent below its target at the desired torque range. This accuracy was within the Australian Standard 4115-1993 of +/- 4 per cent.

Heat exchanger housing and insert examination

The attachment bolts were removed from the inserts to facilitate removal of the gasket from the fuel pipe for re-fitment to the new oil/fuel heat exchanger. The oil/fuel heat exchanger, gasket and inserts were examined by the operator and then sent to the Australian Transport Safety Bureau (ATSB) for further technical examination.

Examination by the ATSB of the supplied components showed that sufficient force had been applied to all four of the threaded inserts to pull them away from the body of the oil/fuel heat exchanger complete with thread material. An examination of the four blind holes in which the inserts had been tapped, revealed that the internal threads had been stripped (Figure 3).

Figure 3: Close view of one of the threaded inserts showing 'stripped' thread material from the heat exchanger

The examination also revealed that all four of the inserts had been pulled into the aluminium alloy substrate of the gasket. Three of the inserts had been completely pulled through the gasket (Figures 4 and 5), while the fourth had been pulled partially into the gasket.

Figure 4: Close-up of a threaded insert from the gasket assembly

Figure 5: Opposite view of the insert from Figure 4, showing it had been pulled completely through the gasket

Previous maintenance issues

The aircraft operator contracted the maintenance of its aircraft to a third-party maintenance organisation. That organisation provided the technical staff that carried out the line maintenance activities. The operator advised that there had been a number of previous maintenance issues regarding incorrect tightening of components. As a result, the operator ensured that the engine manufacturer's maintenance-related IFSD newsletters were posted on notice boards in the relevant airport maintenance areas.

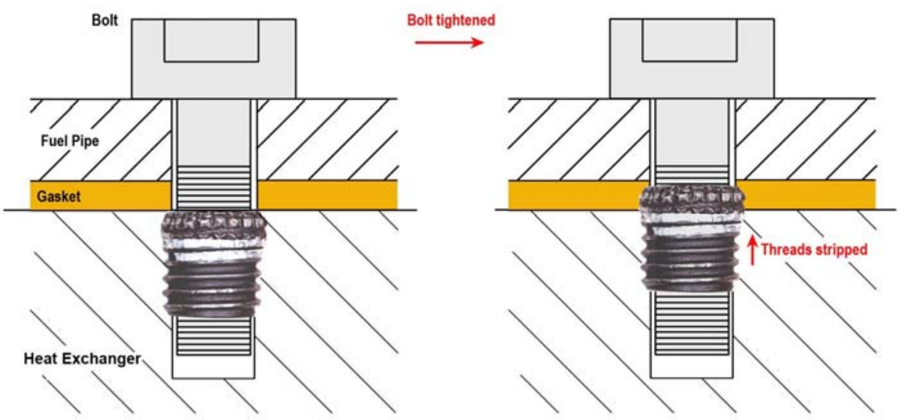
Since this incident, the aircraft operator has ceased to utilise the third-party maintenance organisation for its line maintenance and has established an internal maintenance organisation.

ANALYSIS

The investigation found that the fuel loss experienced on the number-2 (right) engine was the result of the return fuel pipe separating from the inlet of the oil/fuel heat exchanger. The examination of the components found that the threaded inserts that had been tapped into the blind holes on the heat exchanger's fuel inlet flange had sufficient force applied to them to be pulled from their location.

Thread material from the oil/fuel heat exchanger was still located within the thread of the inserts, indicating that exposure to excessive shear stress had occurred. The thread failure was a direct result of over-torque of the attachment bolts. The drawing of the inserts through the gasket material (Figure 7) indicated that the failure of the inlet flange threads would have occurred during the bolt tightening sequence during the previous maintenance activity to install the fuel pump package, 2 days earlier. Had the inserts failed due to flexing/vibration of the return fuel line during service subsequent to the fuel pump package fitment, the inserts would not have penetrated the gasket material. The lack of damage to the gasket and flange surface, as reported by the aircraft maintenance engineer (AME), indicated that the inserts had not commenced migration prior to the fitment of the fuel pipe.

Figure 7: Bolt tightening sequence showing thread stripping and insert migration into the gasket



The lack of fuel leakage from the oil/fuel heat exchanger during the post-installation engine run and the three subsequent flights, indicate that a degree of gasket sealing had occurred following fitment of the fuel pipe. However, subsequent in-service movement of the fuel pipe resulted in the eventual complete release of the inserts, leading to the fuel leak.

The AME reported tightening the four attachment bolts to 60 pound-inches. The maintenance manual indicated that, for the modification status of the oil/fuel heat exchanger, the maximum torque applied to the bolts should have been 53 pound-inches. The AME's lack of awareness of the different modification states applicable to the oil/fuel heat exchanger and the differing torque values to be used, may explain the incorrect torque value applied to the attachment bolts.

FINDINGS

From the evidence available, the following findings are made with respect to the fuel system event, near Rockhampton, Qld on 13 August 2007 involving Boeing 737-700, VH-VBR, and should not be read as apportioning blame or liability to any particular organisation or individual.

Contributing safety factors

- The fuel imbalance and fuel loss experienced on the number-2 (right) engine occurred due to partial separation of the main fuel return pipe from the oil/fuel heat exchanger unit.
- Separation of the fuel pipe was due to the failure of all four internal threads on the heat exchanger as a result of being over-torqued.
- The four attachment bolts were tightened beyond the specified value of 53 pound-inches for the modification state of the oil/fuel heat exchanger.
- The aircraft maintenance engineer (AME) was not aware of the different modification states of the oil/fuel heat exchanger and differing bolt torque values to be used.
- The level of supervision of the AME by the licensed aircraft maintenance engineer (LAME) was affected by his involvement in other tasks.

Other key findings

- The engine manufacturer had issued service bulletins to modify the heat exchanger pipe attachments to key lock inserts to prevent this type of occurrence.
- The threaded insert modification had not been carried out on the oil/fuel heat exchanger as the engine had not undergone a shop visit prior to the incident.

SAFETY ACTIONS

Aircraft operator

As a result of this occurrence, the aircraft operator notified the subsequent maintenance provider of the circumstances surrounding this incident and received assurance that their process, procedures and oversight were adequate to prevent a recurrence.

COUPLING NUT. IF YOU DO NOT USE TWO WRENCHES, DAMAGE TO THE EQUIPMENT CAN OCCUR.

(11) Do these steps to install the fuel tube [31] and the fuel tube [37] on the fuel pump package [1]:

(a) Remove the protective covers from the fuel tubes [32], fuel tube [37], hose [33], and the applicable cover from the fuel pump package [1].

(b) Lubricate these parts:

WARNING: **DO NOT LET THE OIL STAY ON YOUR SKIN. USE THE OIL IN AN AREA WITH GOOD VENTILATION. THE OIL IS POISONOUS AND CAN BE ABSORBED THROUGH YOUR SKIN. THE OIL FUMES CAN IRRITATE YOUR RESPIRATORY TRACT.**

1) Lubricate the gasket [32] and gasket [38] with D00623 oil [CP5066].

2) Lubricate the threads of the bolts [30], [36], [39], and [41] with D00601 grease [CP2101].

3) Lubricate the threads of the nipples with D00623 oil [CP5066].

(c) Put the fuel tube [37] and the gasket [38] in the correct position between the fuel pump and the hose [33].

VOZ ALL PRE CFM56-7B-79-0023 OR PRE CFM56-7B-72-0468

(d) Use your hands to install the four bolts [39] that hold the fuel tube [37] and the gasket [38] to the and the four washers [43] to the fuel pump package [1].

VOZ ALL POST CFM56-7B-79-0023 AND POST CFM56-7B-72-0468

(e) Use your hands to install the four bolts [39] that hold the fuel tube [37] and the gasket [38] to the fuel pump package [1].

VOZ ALL

(f) Use your hands to connect the fuel tube [37] to the hose [33].

(g) Use your hand to install the nut [35], bolt [36], and the clamp [34] that hold the fuel tube [37] to the bracket.

(h) Put the fuel tube [31] and the gasket [32] in the correct position between the fuel pump and the fuel tube [37].

(i) Use your hands to install the four bolts [30] that hold the fuel tube [31] and the gasket [32] to the fuel pump package [1].

(j) Use your hands to connect the fuel tube [31] to the fuel tube [37].

1) Use your hands to install the nut [40], bolt [41], and clamp [42] that hold the tube [31] to the bracket [53].

(k) Make sure that the fuel tube [31] and [37] are in their correct positions and do not touch other components.

(l) Tighten the bolts [30] (that hold the fuel tube [31] to the fuel pump) to 49-53 pound-inches (5.5-6.0 Newton-meters).

VOZ ALL PRE CFM56-7B-79-0023 OR PRE CFM56-7B-72-0468

(m) Tighten the bolts [39] (that hold the fuel tube [37] to the fuel pump package [1] to 49-53 pound-inches (5.5-6.0 Newton-meters).

VOZ ALL POST CFM56-7B-79-0023 AND POST CFM56-7B-72-0468

(n) Tighten the bolts [39] (that hold the fuel tube [37] to the fuel pump package [1] as follows:

NOTE: You must apply the following steps at each of the four bolts

[39] to cross-tighten them.

Start with the first bolt at the top left side of the port.

The second bolt is at the diagonal opposite location of the first bolt.

The third bolt is at the bottom left side of the port.

The fourth bolt is at the diagonal opposite location of the third bolt.

1) Tighten the bolts [39] to 40-45 pound-inches (4.52-5.08 Newton meters).
2) Loosen the bolts [39] but do not remove them.
3) Measure the locking torque of each bolt [39].
   a) The torque value must be 2.2-15 pound-inches (0.24-1.69 Newton meters).
   b) If not, replace the bolt [39].
4) The torque value must be 2.2-15 pound-inches (0.24-1.69 Newton meters).
5) Add the locking torque value of bolts [39] recorded before.
6) Tighten the bolts [39] to a final torque between 42.2-60 pound-inches (4.77-6.78 Newton meters).

VOZ ALL

(o) Make sure that the fuel tubes [31] and [37] stay in their correct positions as you tighten the coupling nuts.
   1) Use two wrenches to tighten the coupling nut, between fuel tube [37] and the hose [33], to a torque of 900-1100 pound-inches (100-125 Newton meters).
   2) Use two wrenches to tighten the coupling nut, between the fuel tubes [31] and [37], to a torque of 900-1100 pound-inches (100-125 Newton-meters).

(p) Tighten the nuts [35] and [40] that hold the clamps [34] and [42] to 98-110 pound-inches (11.0-12.5 Newton-meters).

]§

SUBTASK 73-11-01-420-013-F00§[

(12) Do these steps to connect the oil tube [20] on the fuel pump package [1]:
   (a) Remove the protective cover from the oil tube [20] and the applicable cover from the servo fuel heater.
   (b) Lubricate these parts:

WARNING: DO NOT LET THE OIL STAY ON YOUR SKIN. USE THE OIL IN AN AREA WITH GOOD VENTILATION. THE OIL IS POISONOUS AND CAN BE ABSORBED THROUGH YOUR SKIN. THE OIL FUMES CAN IRRITATE YOUR RESPIRATORY TRACT.

1) Lubricate the gasket [21] with D00623 oil [CP5066].
2) Lubricate the threads of the bolts [19] with D00601 grease [CP2101].

FIG. EFFECTIVITY: VOZ ALL

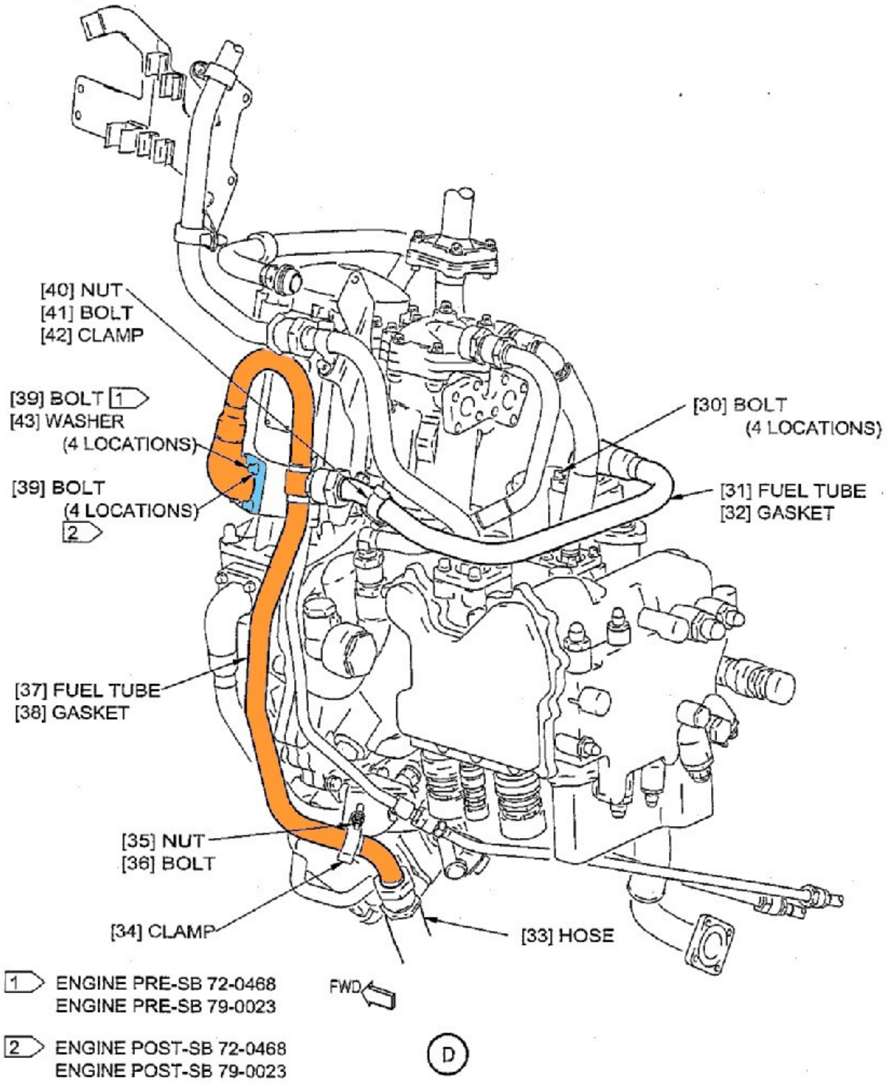


Figure 402. Fuel Pump Package Installation Sheet 4

APPENDIX B: SOURCES AND SUBMISSIONS

Sources of information

The aircraft operator

Submissions

Under Part 4, Division 2 (Investigation Reports), Section 26 of the Transport Safety Investigation Act 2003, the Executive Director may provide a draft report, on a confidential basis, to any person whom the Executive Director considers appropriate. Section 26 (1) (a) of the Act allows a person receiving a draft report to make submissions to the Executive Director about the draft report.

Submissions were received from the aircraft operator. The submissions were reviewed and, where considered appropriate, the text of the report was amended accordingly.