RNF

AIRCRAFT ACCIDENT REPORT

Fire during landing roll

M-01508/AIG-04

TF-ARS
Air Atlanta Icelandic
Zia International Airport
Dhaka, Bangladesh
March 25, 2008

Icelandic Aircraft Accident Investigation Board

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Synopsis

The Aircraft Accident Investigation Board in Iceland (IAAIB) was informed of the accident, as a state of registry, by the owner/operator of the aircraft on the 25th of March 2008, first by e-mail at 09:13 UTC and then by phone at 10:05 UTC. Further information regarding the accident was provided by e-mail on the same day at 20:34 UTC. The Civil Aviation Authorities of Bangladesh (CAAB) immediately conducted a preliminary investigation of the accident. On the 27th of March, the CAAB delegated further conduct of the investigation to the Icelandic authorities as the state of registry. At that time, the Icelandic Aircraft Accident Investigation Board appointed an Investigator in Charge (IIC) of the investigation. In accordance with Annex 13, the National Transportation Safety Board (NTSB) appointed an Accredited Representative (ACCREP) to the investigation as a state of manufacturer. The ACCREP planned to travel to the accident site along with his advisors from the aviation authorities as well as the aircraft and engines manufacturer, i.e. advisors from FAA, Boeing and P&W.

The IIC arrived at the accident site along with his advisors from the Icelandic Civil Aviation Authorities (ICAA) and the aircraft operator on the 29th of March 2008. In co-operation with CAAB and NTSB, the IIC started the on-site investigation immediately upon arrival. On the 31st of March, the on-site investigation team found the probable cause of the accident and informed the NTSB ACCREP as well as CAAB. The NTSB ACCREP and his advisors then decided not to travel to the accident site.

The flight of TF-ARS was a scheduled flight from Medina (Saudi Arabia) to Dhaka, (Bangladesh). During the landing roll at Zia International Airport at Dhaka, the strut/engine area No. 3 caught fire. The aircraft came to a rest on a taxiway at the end of the runway where all 307 passengers and 18 crew members evacuated through emergency exits. The fire department at Zia International Airport managed to extinguish the fire but the aircraft was later evaluated beyond economical repair.

A fuel leak from a fuel line coupling at strut No. 3 was determined as the cause of the fire/accident. The coupling was incorrectly assembled most probably during the aircraft's last "C-check", completed 6 months prior to the accident.

1 Factual information

Factual information	
Place:	Zia International Airport, Dhaka, Bangladesh.
Date:	25th of March 2008.
Time[1]**:**	08:30.
Aircraft:	
• **type**	Boeing 747-300.
• **registration**	TF-ARS.
• **year of manufacture**	1983.
• **serial number**	22996.
• **CoA**	Valid until 31st of July 2009.
• **Nationality**	Icelandic.
• **Engine type**	JT9D-7R4G2.
Type of flight:	Commercial air transport (passenger).
Persons on board:	Passengers: 307. Crew: 18.
Injuries:	Minor during evacuation (both crew and passengers).
Nature of damage:	Aircraft damaged beyond economical repair.
Short description:	Fire at strut/engine area No. 3.
Owner:	Air Atlanta Icelandic.
Operator:	Air Atlanta Icelandic.
Weather:	220°/03 knots, visibility 5000 meters, QNH 1007.2.
Meteorological conditions:	Visual Meteorological Conditions (VMC).
Flight rules:	Instrument Flight Rules (IFR).

[1] All times in this report are UTC (Coordinated Universal Time)

1.1 History of the flight

TF-ARS (B747-300) was on a scheduled flight from Medina (Saudi Arabia) to Dhaka (Bangladesh), flight number SVA810. The flight crew consisted of a commander, co-pilot and a flight engineer. The cabin crew consisted of 15 crew members including one senior cabin attendant. Additionally to the cabin crew, one “off duty” cabin crew member was in the cabin.

According to the commander, the flight from Medina and the landing at Dhaka was uneventful. During the landing roll, approximately 50 seconds after touchdown, the flight crew received a call from the tower controller where the tower controller inquired whether the aircraft was under control. The flight crew responded to the call by stating that the aircraft was completely under control and asked what the problem seemed to be. The controller then informed the flight crew that fire was observed at the right wing area. At this point the Aerodrome Fire Operator had already activated the fire fighters as well as the rescue team. As soon as the controller had informed the flight crew about the fire, the flight crew received a No. 3 engine fire alarm. The co-pilot immediately discharged the first engine fire bottle and the flight crew requested fire fighter assistance and shut down all engines. The co-pilot waited 20 seconds until the second fire bottle was discharged. At this time the commander called the senior cabin attendant to the flight deck using the public address system (PA). This command was followed by a command to the cabin crew to remain seated[2]. The commander informed the senior cabin attendant of the situation and instructed him to evaluate the situation and to evacuate the passengers if necessary. The senior cabin attendant went back down to the main deck and saw the smoke and the fire through the windows. He then commanded the cabin crew as well as passengers, by using a megaphone, to evacuate the aircraft. The cabin attendant at location L2 (see figure 6-7, page 21) had already operated the emergency exit and started evacuating the passengers. Cabin attendants at locations L1 and R2 (see figure 6-7, page 21) also

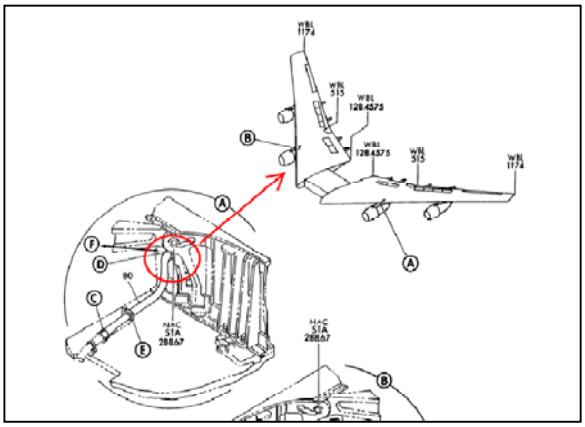


Figure 1: Location of fuel leak

[2] According to the Operators Operation manual, this means: Cabin Crew Members - keep passengers seated – Prepare for normal Arrival.

operated their respective emergency exits. After realizing that smoke and fire were at the right hand side, the emergency exit at R2 was blocked by one of the cabin attendants. All passengers managed to evacuate without serious injuries and the fire department at Zia International Airport managed to extinguish the fire successfully. The damage to the aircraft was later evaluated as beyond economical repair.

1.2 Injuries to persons

Some of the passengers and two crew members suffered minor injuries during the evacuation process. The injuries were burn marks to the skin due to contact with the escape slides. The IAAIB could not confirm the exact number of passengers that suffered injuries. The number of minor injuries to passengers in Table 1 is based on the crew's estimation.

Injuries	*Crew*	*Passengers*	*Total in the aircraft*	*Others*
Fatal	0	0	0	Not applicable
Serious	0	0	0	Not applicable
Minor	2	15	0	Not applicable
None	16	292	0	Not applicable
TOTAL	18	307	0	Not applicable

Table 1: Injuries to persons

1.3 Damage to aircraft

Soon after landing, the fire started in the strut/engine area No. 3. The commander shut down all engines and the aircraft remained on the taxiway until all passengers and crew members had evacuated the aircraft and the fire had been extinguished. The aircraft was damaged in the strut/engine area No. 3 as well as in the surrounding sections of the right hand wing. The aircraft was evaluated beyond economical repair. Figure 2 shows the damage to the aircraft at the fire area (strut and engine No. 3).

Figure 2: Fire damage to right hand wing, strut and engine No. 3

1.4 Other damage

None.

1.5 Personnel information

Commander	
Age, sex:	55 year old, male.
License:	Holder of ATP license issued by the Australian CAA. License was valid.
Medical certificate:	First class, valid.
Ratings:	B747-200/300.
Experience:	Total all types: 18,137 Total on type: 5,637 Last 90 days: 78:44 Last 28 days: 43:37 Last 24 hours: 0:00
Previous rest period:	More than 24 hours.

Co-pilot	
Age, sex:	39 year old, male.
License:	Holder of ATP license issued by the Italian CAA. License was valid.
Medical certificate:	First class, valid.
Ratings:	B747-200/300.
Experience:	Total all types: 7,161 Total on type: 261:19 Last 90 days: 66:06 Last 28 days: 29:08 Last 24 hours: 0:00
Previous rest period:	More than 24 hours.

Flight engineer		
Age, sex:	49 year old, male.	
License:	Holder of flight engineer license issued by the South African CAA. License was valid.	
Medical certificate:	First class, valid.	
Ratings:	B747-200/300.	
Experience:	Total all types:	9,447
	Total on type:	8,478
	Last 90 days:	167:22
	Last 28 days:	14:35
	Last 24 hours:	0:00
Previous rest period:	More than 24 hours.	

1.6 Aircraft information

During the on-site investigation, a fuel leak was discovered at one of the main fuel line couplings. The leak was found where the main fuel line is coupled to the front spar for engine No. 3. By moving the fuel line a little by hand, a fuel leak was observed (See Figure 14). After opening the coupling it was discovered that one of the two retaining rings was missing (See Figure 15) and the O-ring was in the wrong position (not on the fuel line). Therefore the O-ring was probably not sealing as it should when correctly installed.

The total flying hours of the aircraft was 99,327:35 and total cycles were 18,779.

Maintenance log and maintenance documentation

According to the aircraft journey and technical log for the flight prior to the accident there were no defects reported.

On the 18th of March 2008, or seven days prior to the accident, a defect was reported as "ENG#3 fuel flow erratic". On the 20th of March the fuel flow transmitter was replaced and its operation was found satisfactory.

On the 23rd of December 2007, engine No. 3 flamed out during cruise at FL 360 and was shut down in accordance with the QRH (Quick Reference Handbook). According to the aircraft journey and technical log for that flight (page No. 187902)[3], there was no cause found that could explain the flame out.

On the 12th of November 2007, the engine No. 3 spooled down during cruise at FL 360 with no thrust response, resulting in a drop of engine oil pressure. The engine was shut down by the crew. According to the aircraft journey and technical log for that flight (page No. 162543)[4], the maintenance crew was unable to duplicate this problem during the defect rectification.

[3] All parameters normal at GND idle IAW AMM 71-00-00 Engine fuel filter chk, bld valves chk, inlet/exhaust nil findings, starter duct nil.

[4] Nil findings as per AMM 72-61-00, nil findings by inspecting oil filter, engine inlet and exhaust visually inspected (all satisfied). Engine run-up, unable to duplicate problem.

Last major maintenance prior to the accident

Approximately six months prior to the accident, the aircraft was maintained in accordance with a "C"-check maintenance program. The maintenance was completed in accordance with EASA Part 145 approval[5] oversight by the Civil Aviation Authorities of UK in accordance with contract between EASA and UK CAA no. 145.0100[6]. Within the "C"-check, one of the tasks was to replace all O-ring seals in the fuel feed line couplings in the engine struts.

Following the replacement of the O-rings a leak test was made by following AMM 28-22-07 method 2 (see appendix 5).

Service letter

According to manufacturer's service letter (747-SL-28-052-B, ATA: 2822-50, dated 30th of August 1998), the manufacturer provided a recommended replacement interval of the O-rings. This replacement is based on the fact that during scheduled maintenance on a CF6-50 powered airplane, 16 out of 20 replaced strut fuel line O-rings where found aged or deteriorated. See service letter in Appendix 1.

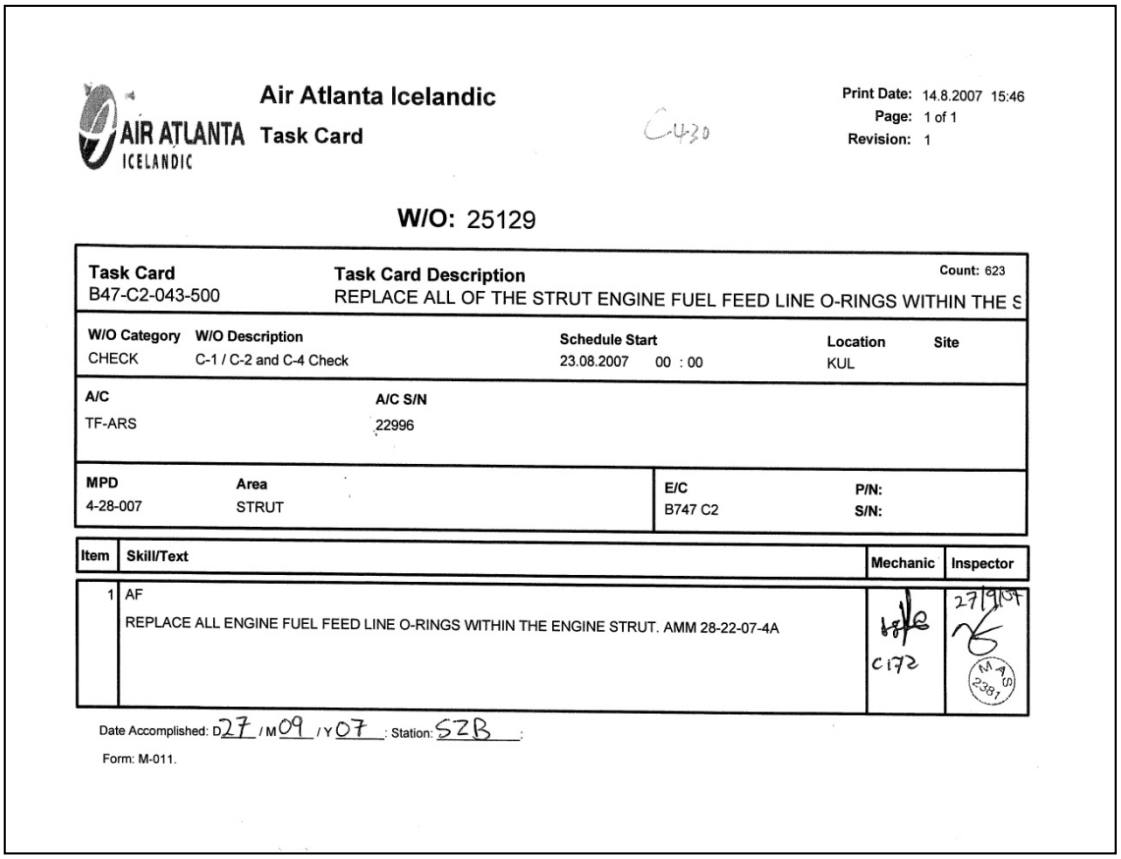
[5] EASA Part 145 is the Implementing Regulation issued by EASA (European Aviation Safety Agency) for the aircraft maintenance sector (Maintenance Organization Approval) establishing the requirements to be met by an organization to qualify for the issue or continuation of an approval for the maintenance of aircraft and components.

[6] There is a contract between EASA and UK CAA, whereby UK CAA conducts the regulatory oversight of non–EU organization approvals such as Malaysian Airline System (MAS).

Task Card

The operator created his own task card, B47-C2-043-500 (see Figure 3). The created task card was based on a task card from the manufacturer, 28-22-07-4A, see appendix 3. The maintenance division created its own task card for the work after delivering the task card from the operator, see appendix 4. The maintenance division however signed the task card created by the operator.

Below is the signed task card for the replacement of the O-rings within the fuel feed line coupling (B47-C2-043-500). The task card was signed by two licensed aircraft maintenance engineers (LAE), but not the mechanic that actually performed the task.



Air Atlanta Icelandic

AIR ATLANTA ICELANDIC Task Card

C430

Print Date: 14.8.2007 15:46
Page: 1 of 1
Revision: 1

W/O: 25129

Task Card	Task Card Description	Count: 623
B47-C2-043-500	REPLACE ALL OF THE STRUT ENGINE FUEL FEED LINE O-RINGS WITHIN THE S	

W/O Category	W/O Description	Schedule Start	Location	Site
CHECK	C-1 / C-2 and C-4 Check	23.08.2007 00 : 00	KUL	

A/C	A/C S/N
TF-ARS	22996

MPD	Area	E/C	P/N:
4-28-007	STRUT	B747 C2	S/N:

Item	Skill/Text	Mechanic	Inspector
1	AF REPLACE ALL ENGINE FUEL FEED LINE O-RINGS WITHIN THE ENGINE STRUT. AMM 28-22-07-4A	C172	27/9/07

Date Accomplished: D 27 / M 09 / Y 07 : Station: SZB

Form: M-011.

Figure 3: Signed task card for the replacement of the O-rings

This task card was replaced by task card 4-28-007-02-3 in October 2003. The work of the task card above was however made in accordance with task card 4-28-007-02-3 during the “C”-check, see appendix 3.

Fuel information

According to the aircraft fuelling form, TF-ARS departed Medina on the 25th of March with fuel as follows:

Tank	Indicator reading after fueling (Kgs.)
1R	1,300
1M	12,600
2M	34,900
C	20,400
3M	37,000
4M	12,600
4R	1,300
Total	120,100

Table 2: Fuel quantity in each tank at take-off prior to the accident.

According to the flight crew's landing "bug card", calculated landing fuel at Zia International Airport was 47,500 Kgs.

1.7 Meteorological information

The weather conditions at Zia International Airport according to the meteorological service in Bangladesh were as follows:

Time (UTC)	Visibility meters	Wind direction	Wind (KNT)	Cloud base	QNH	Temp °C	Td °C
07:50	5000	260	07	Few 2.000‘	1007.9	32	19
08:50	5000	220	03	SKC	1007.2	32	18
09:50	5000	180	09	SKC	1006.9	32	20

Table 3: Meteorological information, 25th of March 2008

1.8 Aids to navigation

N/A.

1.9 Communications

The communications between the flight deck and the tower control were normal during the approach and landing. After approximately 50 seconds of landing roll the communications were as follows:

TIME	FROM	TO	COMMUNICATION
08:30:07	TWR	SVA810	SVA810 Dhaka
08:30:10	SVA810	TWR	Go ahead
08:30:12	TWR	SVA810	Ok, confirm your aircraft is under control
08:30:15	SVA810	TWR	Affirm, completely under control, what seems to be the problem?
08:30:20	TWR	SVA810	Roger, we saw some fire on your right wing
08:30:27	SVA810	TWR	Stand by
08:30:32	TWR	SVA810	On your right wing we saw some fire
08:30:35	TWR	SVA810	It has been, it has been --- right wing, you can stop, you can stop clearing the RWY
08:30:40	SVA810	TWR	Ok. We are clearing the RWY, we shut down the engine Nr. 3 -------- SVA810
08:30:45	TWR	SVA810	SVA810 Shut down all engines, all engines, shut down all engines
08:30:50	TWR	SVA810	SVA810 shut down all engines
08:31:08	SVA810	TWR	We will shut down all engines SVA810
08:31:10	SVA810	TWR	Ok. We have shut down all engines SVA810
08:32:28	TWR	SVA810	We still --------- smoke on your right, smoke on your right, we can see it burning, under carriage burning
08:32:42	SVA810	TWR	Ok. Confirm that you still see a smoke on right hand side
08:32:48	TWR	SVA810	Affirm, still we can see fire under carriage, fire vehicles are moving
08:32:50	SVA810	TWR	Ok. Send fire fighter as soon as possible
08:33:00	TWR	SVA810	Ok. Fire fighter is on the way, fire fighter is on the way. Already, already one reached behind you, another is in front of you
08:33:56	SVA810	TWR	We need fire fighters, as soon as possible. Still on the way, we are waiting -------- as soon as possible, go ahead
08:34:09	TWR	SVA810	Ok. Fire fighting vehicles is behind you, already extinguishing fire and one is in front of you and other two is running also
08:34:16	SVA810	TWR	Oh, thank you very much, we now see one in front of us -------- yes keep ----------
08:34:26	TWR	SVA810	Copied sir
08:34:29	SVA810	TWR	Thank you we are evacuating the people now

Table 4: Recorded communication between tower controller and the flight crew

The communications listed above are based on the tape transcript recorded at Zia International Airport. The frequency of transmission was 118.3 MHz's.

1.10 Aerodrome information

There is one runway at Zia International Airport (DHAKA), runway 32/14. The aircraft was landing on runway 14 at the time of the accident. The runway is 10,499 feet long (3200m). At the end of the runway, there is a taxiway to the left, taxiway “S”. The aircraft was stopped on taxiway “S”, see Figure 4.

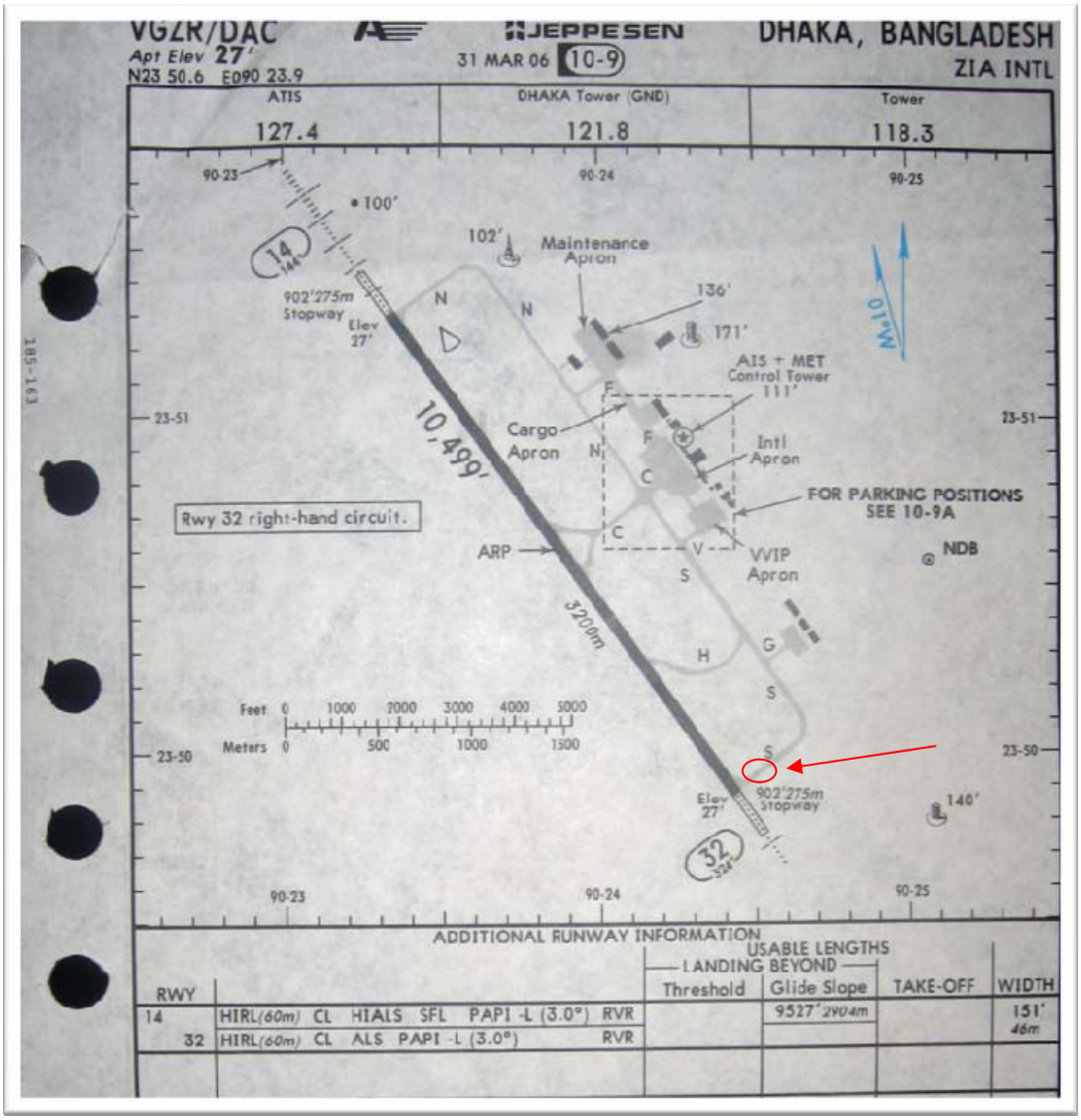


Figure 4: Zia Intl. Airport at Dhaka - Jeppesen chart dated 31st March 2006

1.11 Flight recorders

The aircraft was equipped with a Flight Data Recorder (FDR) and 30 minutes Cockpit Voice Recorder (CVR). The recorders were removed and the data was retrieved successfully. The CVR recorded sound until the engines were shut down.

1.12 Wreckage and impact information

N/A.

1.13 Medical and pathological information

N/A.

1.14 Fire

During the landing roll of flight SVA810, the air traffic controller as well as the Aerodrome Fire Operator (AFO) who was on look-out duty at the watch tower, observed smoke and fire under the right wing of the aircraft. The controller communicated with the flight crew and the AFO instantly informed the “duty fire leader” in order to activate the fire and rescue team.

The fire and rescue team was at the aircraft approximately 2 ½ minutes after the smoke/fire was observed and started extinguishing the fire immediately. The fire department used three vehicles to extinguish the fire by using a total of 1,050 liters of foam and 38,000 liters of water.

Figure 5: Fire vehicles at the accident site

1.15 Survival aspects

TF-ARS was equipped with twelve emergency exits, six on each side, see Figure 6 and Figure 7.

The cabin crew members heard the commander's announcement over the PA system, "senior to flight deck, senior to flight deck", cabin crew remain seated". The senior cabin crew member went to the flight deck and received information about the fire warning from the flight crew and went back to the main deck to assess the situation. The senior cabin crew member then returned to the upper deck where he met one of the flight crew members at the stairs and was instructed to evacuate the passengers. The senior cabin crew member used the megaphone to communicate. The evacuation command was not given according to the company's evacuation procedure[7].

According to the cabin crew's statement, passengers on the main deck were located at C, D and E zones (L3 – L5) and approximately 30 passengers were on the upper deck (incl. 5 children and 3 infants). The cabin crew opened two emergency exits on the left side (main deck) at zone A and B (L1 and L2), and one on the right side, R2. Approximately 20-30 passengers evacuated through the R2 exit but the exit was then blocked due to the fact that the fire/smoke was on that side of the aircraft.

No other emergency exits were opened. According to the statement of the cabin crew member at location L3, the fire was in his area and he decided not to open the exit. The cabin crew member at emergency exit L5 stated that the passengers stood up as soon as the aircraft stopped. He left his position in order to have the passenger's return to their seats. Since the passengers then started to rush to the open exits at the front of the aircraft, the cabin crew member could not get back to emergency exit L5.

[7] QRH DEC 01/05, T-3 – T4

All passengers and crew members evacuated safely. It was not possible to estimate the time of the evacuation process.

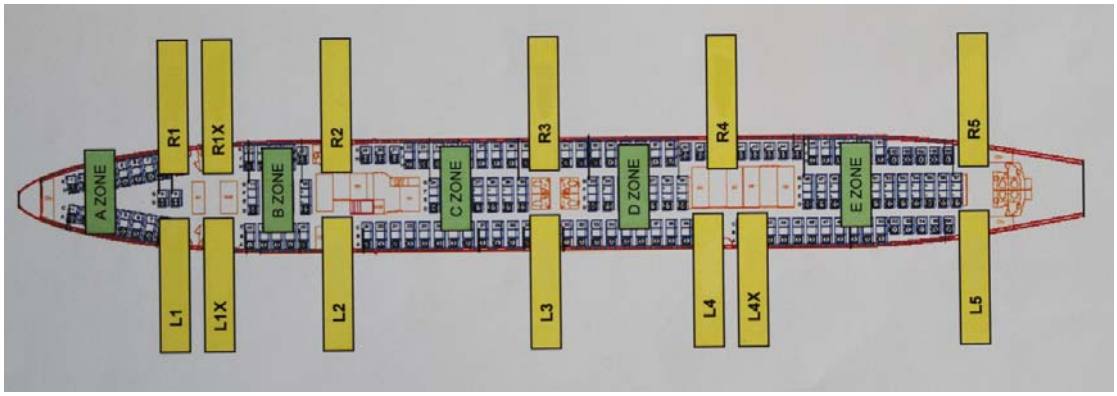


Figure 6: Cabin crew position at main deck (X= no emergency exit)

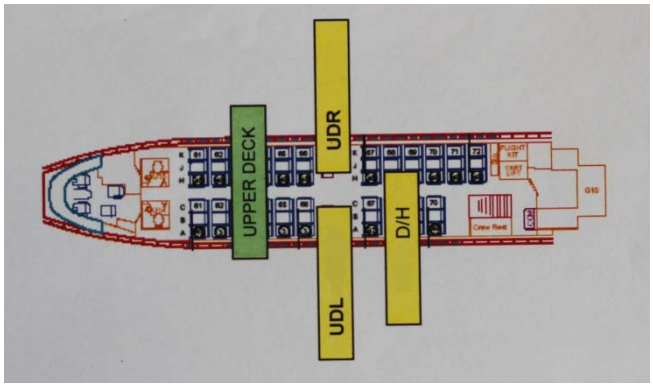


Figure 7: Cabin crew position at upper deck (D/H = Location of the off duty passenger)

Emergency lights were noticed by some of the cabin crew. When the lights were tested during the investigation, all lights worked properly.

1.16 Tests and research

During the investigation, a fuel leak test was conducted by the investigation team at MAS Engineering & Maintenance Division. The leak test was made where the fuel line is coupled at the front spar for engine No. 3. The purpose of the test was to evaluate if the fuel leak could be observed during a standard fuel leak test with the fuel line coupling incorrectly assembled. The test was performed on TF-AAA (B747). The aircraft manufacturer confirmed that the fuel line system in the subject area was identical to the one on the accident aircraft.

The following four tests were conducted:

1. The O-ring and one retaining ring placed as found in engine area No. 3 of TF-ARS (see Figure 8.), i.e. one O-ring within the fitting end and one retaining ring on the ferrule.

Figure 8: Placement of O-Ring and Retaining ring in test 1.

The fuel line was assembled this way and couplings secured hand-tight. The fuel line was pressurized using only one fuel boost pump. The engine ignition circuit breakers were pulled and the engine start lever was placed in the “On” position to open the engine fuel shut-off valve. There was an initial squirt of fuel from around the coupling, a few drops, and then it stopped. The second fuel boost pump was then turned on. No further leak occurred. When the pumps were turned off, fuel started to drip a little for a few seconds from the coupling and then it stopped. The coupling nut was then

loosened by three turns (1/12 to 1/6 of a round each turn). The fuel line was pressurized using one fuel boost pump. No leak occurred. The second fuel boost pump was turned on and the fuel line was gently agitated by hand. No leak occurred. The coupling nut was loosened once more and then fuel started to leak. Gentle agitation by hand of the fuel line increased the rate of fuel leakage. The spar coupling was retightened slightly (by ½ a turn) and the engine/pylon was shaken by pushing against the nose cowl. Only minor dripping was observed.

2. One O-ring and two retaining rings (as found in engine area Nr. 4 of TF-ARS). One O-ring on the front of the ferrule and two retaining rings together also on the ferrule.

Figure 9: Placement of O-Ring and Retaining ring in test 2.

The fuel line was assembled and the coupling nut was secured hand-tight. The fuel line was pressurized using forward and aft fuel boost pumps. The engine ignition circuit breakers were pulled and the engine start lever was placed in the “On” position to open the engine fuel shut-off valve. No leak was evident at this time. The fuel line was also gently agitated by hand. No leak occurred.

3. One O-ring and one retaining ring both on the ferrule

Figure 10: Placement of O-Ring and Retaining ring in test 3.

The purpose of this test was to see if the coupling had been assembled in this way and later the O-ring had moved into the fitting. The fuel line was re-installed and both couplings re-connected and secured hand-tight. It was observed however, that the fuel line moved forward slightly out of the spar coupling when fuel pressure was applied. The fuel line was also gently agitated by hand. No leak occurred.

4. One O-ring in between two retaining ring. Correct assembly.

Figure 11: Placement of O-Ring and Retaining ring in test 4.

The O-ring and two retaining rings were placed correctly in accordance with AMM configuration. The coupling was re-connected and secured hand-tight. The fuel line was pressurized using both fuel boost pump. The coupling nut was then loosened a little more than in test “1”. No fuel leak occurred. The fuel line was gently agitated by hand and still no leak.

The tests above did not take into account in-flight conditions such as lower temperature and other different atmospheric conditions.

1.17 Organizational and management information

The aircraft was owned by the Icelandic operator Air Atlanta Icelandic. At the time of the accident, the aircraft was leased under a wet lease contract[8] to Saudi Arabian Airlines. The aircraft was maintained by MAS Engineering & Maintenance Division in Kuala Lumpur, Malaysia. The maintenance agreement was in accordance with EASA 145, audited by the Civil Aviation Authorities in the United Kingdom (UK).

1.18 Additional information

During the investigation, scratch marks were found on many of the investigated coupling nuts. These marks are most probably from use of pliers used to tighten or loosen the nuts, even though the nut should be hand tightened according to the maintenance manual.

Furthermore the lock wire connected to the coupling nut that was leaking (Figure 12), was fastened in such a way that the coupling nut could rotate slightly.

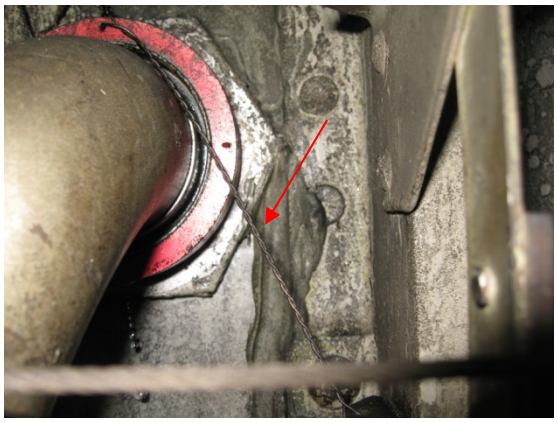


Figure 12: Lock wire in in such a way that the coupling nut could rotate slightly

Figure 13: Lock wire in such a way that the nut is less likely to rotate

[8] Wet lease means that the aircraft was leased with crew and operated by the owner of the aircraft.

1.19 Useful or effective investigation techniques

During the field investigation, the investigation team suspected that the fire could be traced to a fuel leak. However, a fuel leak could not be generated by transferring fuel between tanks or by activating the fuel pumps at the area of engine No 3.

After several attempts to generate a possible fuel leak, a group of people (6-8), from the investigation team, went up on the right wing tip and started to jump on the wing in order to produce wing movements, similar to when the aircraft is in flight or moving on ground. This produced a fuel leak at the flexible half coupling, where the fuel line is coupled to the front spar.

2 Analysis

During the on-site investigation, a fuel leak was discovered at one of the main fuel line couplings. The leak was found where the main fuel line is coupled to the front spar for engine No. 3. By moving the fuel line a little by hand, a fuel leak was observed (See Figure 14). After opening the coupling it was discovered that one of the two retaining rings was missing (See Figure 15) and the O-ring was in the wrong position (not on the fuel line). Therefore the O-ring was probably not sealing as it should when correctly installed. Figure 16, shows a comparable coupling in the front spar for engine No. 2. In Figure 16, the O-ring is correctly installed on the fuel line, i.e. between two retaining rings.

Figure 14: Coupling at front spar for engine No. 3

Figure 15: Coupling at front spar for engine No. 3 (where the fuel leak was detected)

Figure 16: Coupling at front spar for engine No. 2

Examination of other couplings on the aircraft revealed that the coupling at engine No. 1 was also incorrectly assembled. The coupling was found with two retaining rings and one O-ring; however, the O-ring was incorrectly placed, see Figure 17.

Figure 17: Coupling at front spar for engine No. 1

The maintenance data shows that the O-rings were replaced during “C”-check in August 2007, approximately 6 months prior to the accident.

Referring to the tests as listed in chapter 1.16, test and research, IAAIB concludes that the fuel leak test, that was performed during the “C”-check before the accident, may not have revealed visual evidence of fuel leak trough the coupling even though it was incorrectly assembled. Later the coupling nut might have rotated slightly due to the fact that the nut was secured with a lock wire in such a way that it was possible for the nut to rotate enough for the fuel to leak, see Figure 12.

During the investigation, it was not possible to determine which of the maintenance centre mechanics actually replaced the O-rings. The mechanics worked under the supervision of licensed aircraft maintenance engineers (LAE), who signed off the tasks.

At the strut area for each engine, a drain system is designed to drain fuel in case of drips or small running leaks. The drain system was tested at the accident site, both at strut area No. 3 and strut area No. 2, by pouring water on the area where the fuel line couples to the front spar. The drain system was working as expected at strut area No. 2 but the drain was not working as expected at strut area No. 3. This was due to the fact that the drain was blocked by debris.

2.1 Aircraft maintenance manual

When replacing the O-rings within the fuel line couplings, there are three different types of couplings for the mechanics to deal with on this type of aircraft:

- Rigid coupling
- Flexible half coupling
- Flexible full coupling

According to the Boeing Maintenance Manual[9], the use of rigid coupling and flexible couplings is described as follows (see appendix 3):

> *Start connection with a rigid coupling at some fixed point like a bulkhead valve, or pump fitting and observe that last connection point is a flexible full coupling.*

[9]Boeing maintenance manual, 28-22-07 page 40,1 Oct 25/03

Rigid coupling contains one O-ring and one retaining ring. Below is a picture of a rigid coupling.

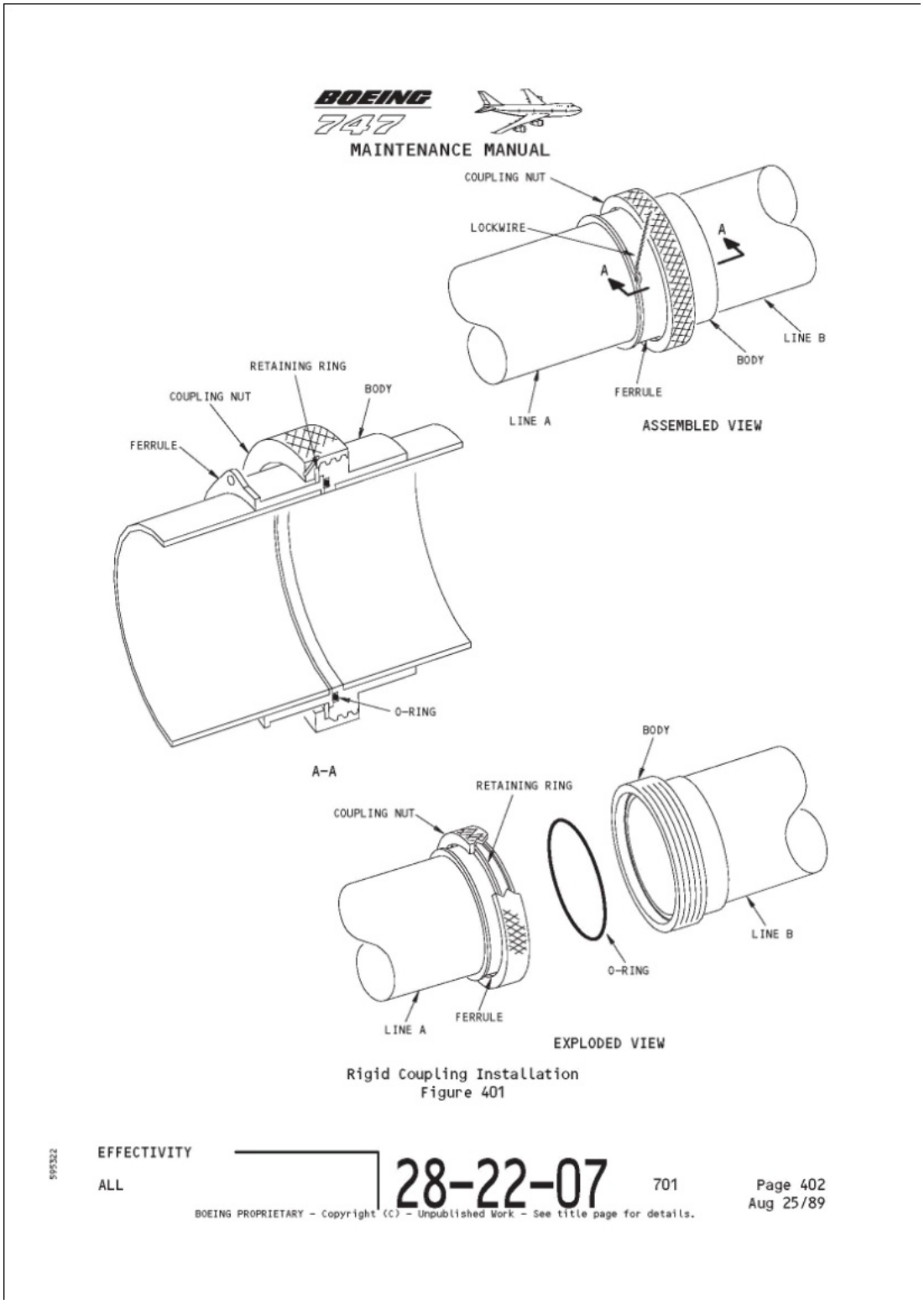


Figure 18: Rigid coupling

Flexible half coupling contains one O-ring and two retaining rings. Below is a picture of a flexible half coupling.

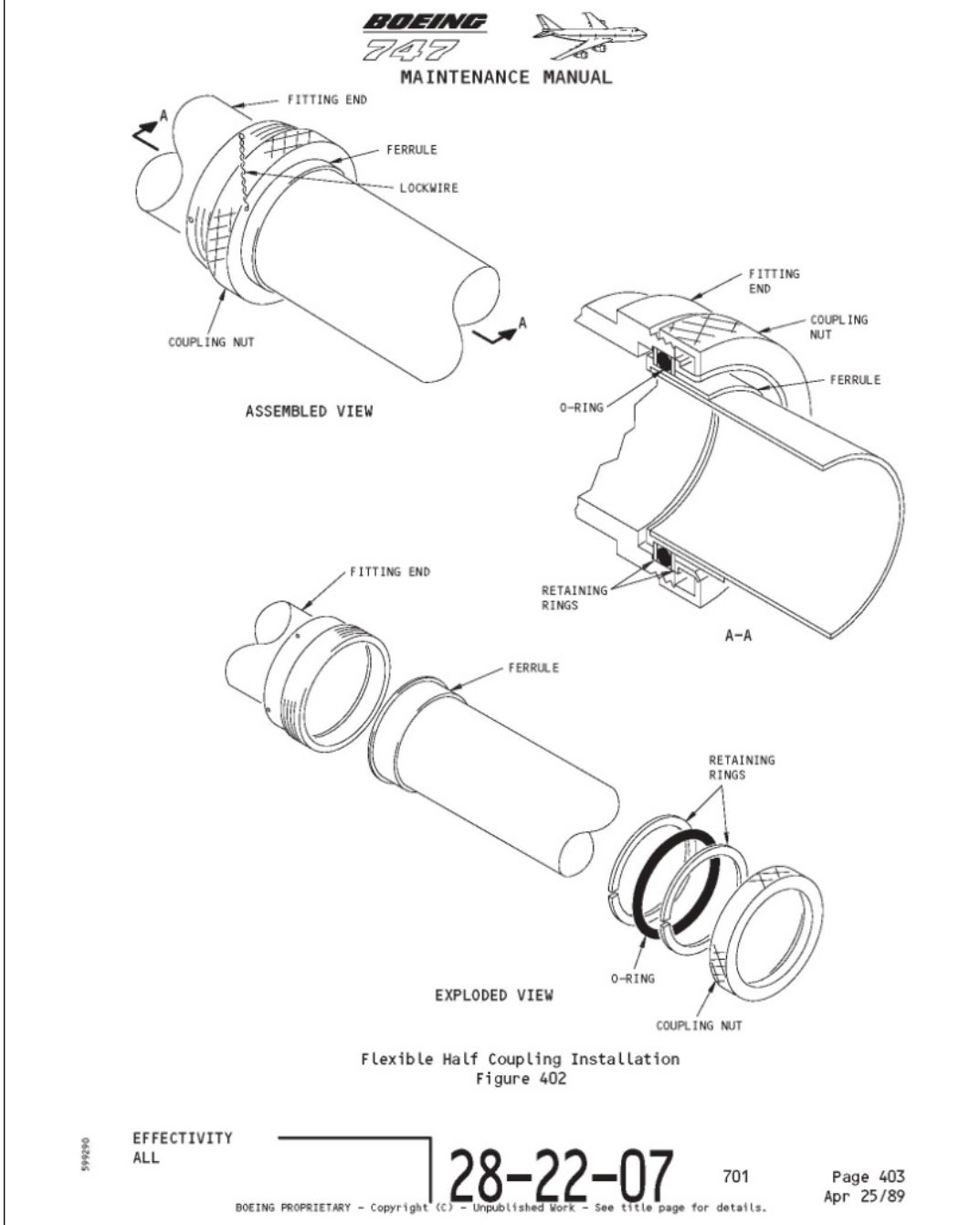
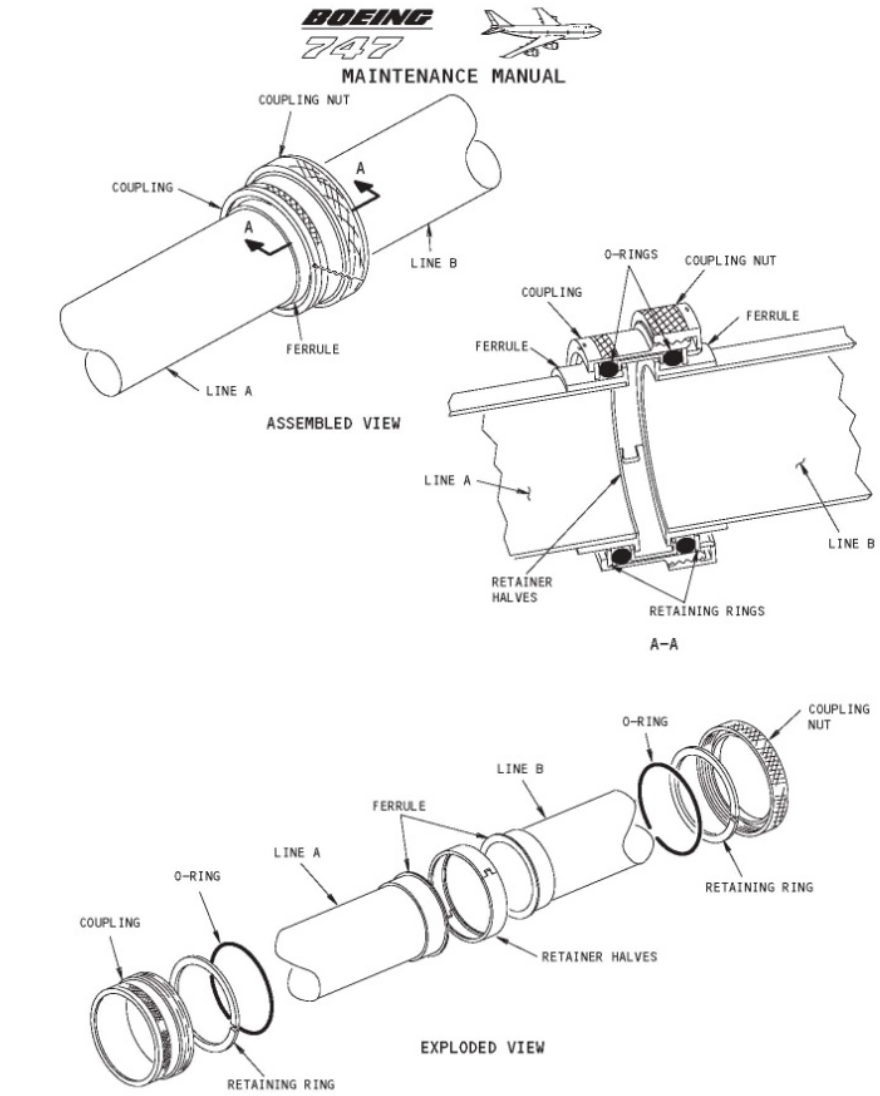


Figure 19: Flexible half coupling

Flexible full coupling contains one O-ring and two retaining rings. Below is a picture of a flexible full coupling.



Flexible Full Coupling Installation
Figure 403 (Sheet 1)

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Figure 20: Flexible full coupling

When working on the coupling at the front spar, the work instructions for flexible half coupling should be used. IAAIB finds that the instructions in the aircraft maintenance manual (AMM) were not clear on which type of coupling should be used at different locations.

The investigation team recommended to the manufacturer that this should be made clearer and in greater detail in order to eliminate the possibility of accidentally confusing the coupling at the front spar with another type of coupling. The aircraft manufacturer responded by sending out a revision in order to give a clearer picture of the coupling at the front spar, see Figure 22.

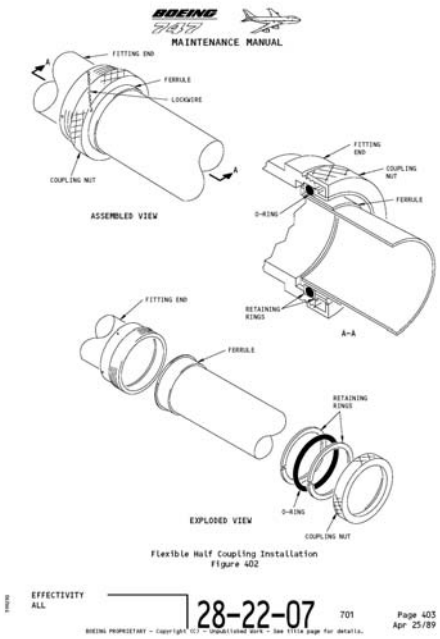


Figure 21: Maintenance manual – Revision used at the "C"- Check prior to the Accident

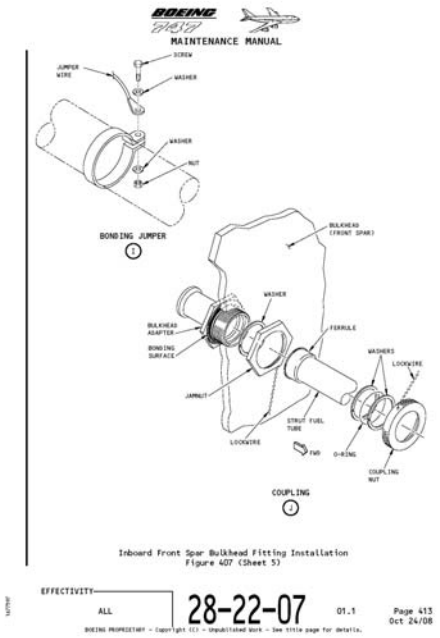


Figure 22: Revised Maintenance Manual after first step of the investigation (see Appendix 6)

3 Conclusions

When TF-ARS was decelerating after landing on runway 14 at Zia International Airport, fuel leak at engine No. 3 resulted in a fire within the strut.

The cause of the fire was that fuel was leaking through the flexible half coupling to the hot surface of the engine. The fuel leak was because the O-ring and retaining rings were not properly assembled within the coupling and one retaining ring was missing.

The IAAIB considers unclear instructions in the aircraft maintenance manual (AMM) to be a contributing factor of the incorrect installation.

Another incorrect installation was also found at the flexible half coupling at the front spar for engine No. 1. However there were no signs of a fuel leak in that area, most likely due to the fact that both the retaining rings and the O-ring were within the coupling even though they were incorrectly placed.

During the investigation, it was not possible to determine the quantity of the fuel leak. However it is likely that the draining system within the strut of engine No. 3 could not manage the fuel leak. According to the manufacturer, the intention of the draining system is to drain drips or small running leaks. Furthermore the drain was clogged by debris, but IAAIB believes that this was a result of the fire.

Two out of six suitable emergency exits on the left side were used (L1 and L2) to evacuate most of the passengers during the emergency evacuation. The reason for not opening doors at location L3, L4 and L5 initially was most likely due to the fact that the commander ordered the cabin crew to remain seated prior to the emergency evacuation. The cabin crew members at locations L3 to L5 most likely did not hear the emergency evacuation command from the senior cabin crew member as he was only using a megaphone. Furthermore these exits were not opened later since the passengers moved aggressively to the opened exits, L1 and L2.

The reason for not opening emergency exit UDL at the upper deck was evaluated by the crew to be too risky for the passengers.

The flight crew discharged both fire bottles for engine No. 3 without managing to extinguish the fire. The flight crew did not discharge fire bottles on other engines. According to the passenger evacuation checklist (see Appendix 2), the crew should discharge all fire bottles before evacuation.

3.1 Findings as to causes and contributing factors

- Incorrect assembly of the flexible half coupling at the front spar of engine No. 3.
- Retaining ring missing in flexible half coupling at the front spar engine No. 3.
- Lock wire fastened in such a way that the coupling nut might rotate slightly.

3.2 Findings as to risk

- Unclear command made to the cabin crew to start emergency evacuation.
- Cabin crew did not open all suitable emergency exits.
- Flight crew did not follow company's procedure regarding evacuation.

3.3 Other findings

- Retaining rings and O-ring incorrectly inserted in the flexible half coupling on engine No. 1.
- Pliers used to tighten or loosen the coupling nuts, even though maintenance manual instructs to only hand tight the nuts.

IAAIB places emphasis on proper installation of the lock wire as well as tightening the coupling nut by hand in accordance with AMM.

4 Safety recommendations and action taken

4.1 Safety recommendation

AAIB Iceland recommends to the MAS Engineering & Maintenance Division to:

1. Ensure that each task will be traceable to the mechanic/mechanics working on the task.

4.2 Safety action taken

1. The aircraft manufacturer made changes to the maintenance manual in order to avoid mixing rigid coupling with flexible half coupling.
2. Chances to the maintenance manual illustrate the placement of the lock wire.
3. Following the accident, a Fleet Team Digest (FTD) was prepared by Boeing and sent out where Boeing recommends that operators review list of "Service Bulletins" (SB's) and "Safety Letters" (SL's) to ensure proper maintenance actions to prevent any further strut fire events.
4. The operator has re-written emergency procedure Section 5, with special emphasize on evacuation techniques, initiative, and assessment of existing emergency situations[10].
5. The operator has re-written chapter 2[11] in the Safety & Emergency Procedures manual (SEP).
6. The operator has been using this accident as a case-study for training.

Reykjavík, May 19, 2011

Aircraft Accident Investigation Board Iceland

[10] Operation Manual, Part A, Volume II, Safety & Emergency Procedures, Section 4.
[11] Standard operating procedures

5 Appendices

Appendix 1. Boeing Service letter

BOEING 747

SERVICE LETTER

Customers Organization

☐ SERVICE ENGINEERING ☐ BOEING COMMERCIAL AIRPLANE GROUP ☐ P.O. BOX 3707 ☐ SEATTLE ☐ WASHINGTON 98124–2207

747–SL–28–052–B
ATA: 2822–50
30 August 1998

SUBJECT: STRUT FUEL FEED LINE COUPLING O–RING REPLACEMENT

MODEL: 747, 747–400 Series

APPLICABILITY: All 747 and 747–400 Airplanes

REFERENCES:

a) In–Service Activities Report No. 86–15, dated 24 July 1986

b) 747 MPD D6–13747–1, Section 4–28–007, Revision "U", dated November 1986

c) Boeing 747 Maintenance Manual 28–22–07, Pages 401–405

d) Boeing 747–400 Maintenance Manual 28–22–07, Pages 431–455

e) Boeing 747–400 Maintenance Manual 28–00–00, Pages 201–207

f) 747–400 MPD D621U400, Revision Level 22 (February 1998), Section 6, Item 28–22–07–04A

SUMMARY:

This Service Letter provides details of in–service experience with Nitrile Rubber and Fluorosilicone O–rings in the strut fuel lines and provides a recommended replacement interval for the O–rings.

BACKGROUND:

Reference a) advised that one operator reported that of twenty engine strut fuel line O–rings replaced on a CF6–50 powered airplane during scheduled maintenance, sixteen showed evidence of aging or deterioration. The aging/deterioration manifested itself as small slivers of rubber partially separated from the O–ring inside diameter. The slivers were still attached, but could be easily pulled loose. The O–rings, P/N MS29513–330, were forwarded to Boeing for analysis. The airplane from which the O–rings were removed had accumulated 42,229 flight hours and 7,879 cycles. The exact age of the O–rings was not known.

DISCUSSION:

Analysis of the MS29513–330 Nitrile rubber O–rings determined that the deterioration was the result of normal aging. Aging of these O–rings is highly dependent upon both storage and use conditions. Exposure to heat, air and ozone will all accelerate aging. In general, the shelf life of these O–rings can be as much as ten years if they have been stored in air tight packages at temperatures not exceeding 100 degrees F (40 degrees C). Once installed, aging under in–service conditions is accelerated.

The fuel feed system O–rings in the strut area appear to be exposed to the most severe conditions. These include a greater likelihood of mechanical damage due to such things as handling during installation, omission of retaining rings or installation of damaged/worn retaining rings during coupling assembly, combined with subsequent normal movement of the strut in–flight. Leakage at these O–rings has resulted in strut/engine fires due to fuel accumulation in the strut area caused by blockage of the strut drain system.

Boeing introduced a new fluorosilicone O–ring, P/N 25988–1–330, into the strut fuel line installation at line position 1070 for PW4000 powered airplanes and line position 1076 for CF6–80C2 powered airplanes. The fluorosilicone O–ring was introduced as a product improvement based on good experience with fluorosilicone O–rings in other fuel system applications. Since incorporation of the part number M25988–1–330 Fluorosilicone O–rings Boeing has received reports of strut fuel leaks from both PW4000 and CF6–80C2 operators. In addition to reports of fuel leaks in–service, Boeing has also received several reports of fuel leaks in the engine pylon area from the Boeing flight line. Several operators have returned M25988–1–330 Fluorosilicone O–rings to Boeing for examination. Engineering analysis of the returned O–rings indicated that several of the O–rings had blackened areas on the internal diameter. This blackening is thought to be due to heat damage or a chemical reaction of the fluorosilicone O–ring with the lubricant used to install the O–ring. However, the exact cause of the blackening could not be determined.

BOEING ACTION:

Reference b) provides a recommendation for replacement of the strut fuel line coupling O–rings on 747 Classic airplanes at "7C" check intervals. Reference f) provides a recommendation for replacement of the strut fuel line coupling O–rings on 747–400 airplanes at "1D" check intervals.

Reference c) and Reference d) have been revised to call for retaining ring replacement, in addition to O–ring replacement, whenever a coupling is disassembled. References c) and d) have also been revised to call for hand tightening of the couplings after reassembly to prevent coupling damage. References c) and e) have been revised to provide updated illustrations for each of the coupling types and to clarify the sequence in which the couplings are assembled.

In response to preliminary reports of strut fuel leaks from couplings with the Fluorosilicone O–rings, Boeing revised the fuel line installation drawings for CF6–80C2 and PW4000 powered airplanes in February 1998, to allow installation of the MS29513–330 Nitrile O–ring as an option to the M25988–1–330 Fluorosilicone O–rings, on airplanes that had been delivered with the fluorosilicone O–rings. Based on the continued reports of fuel leaks due to the Fluorosilicone O–rings, Boeing will revise the strut fuel line installation drawings again, to delete the M25988–1–330 Fluorosilicone O–ring and make the MS29513–330 Nitrile O–ring the only approved O–ring for use in the strut fuel line couplings. This change will be effective from line position 1184 and on.

SUGGESTED OPERATOR ACTION:

To avoid fuel leaks due to O–ring aging, associated deterioration, and to prevent damage to new O–rings due to worn/bent retaining rings, operators should replace the strut fuel feed line coupling O–rings and retaining rings at one of the following intervals, whichever is the most frequent –

1. 7 "C" Checks
2. 1 "D" Check
3. 21,000 Flight Hours

4. Five Years Regardless of Flight Hours

5. Whenever a coupling is disassembled for any reason.

The above recommendation should be considered even if the couplings have not previously been disassembled, or are not leaking and applies to both the M25988–1–330 Fluorosilicone O–ring and the MS29513–330 Nitrile O–ring. However, after removal of a M25988–1–330 Fluorosilicone O–ring, the O–ring should be replaced with a MS29513–330 Nitrile O–ring. After O–ring and retaining ring replacement, operators should ensure the couplings are assembled correctly and do not leak. See References c). d), and e) for details of correct coupling assembly procedures and leak check requirements.

In addition to the above recommended replacement intervals, Boeing further recommends that the M25988–1–330 Fluorosilicone O–rings be replaced with the MS29513–330 Nitrile O–rings prior to the recommended O–ring replacement interval if strut fuel leaks are reported, if the strut fuel line couplings are opened for any reason, or, at an operators discretion during a convenient maintenance interval.

RELATED INFORMATION:

It is estimated that a total of approximately 16 manhours per airplane (4 manhours per strut) will be required for strut fuel line coupling O–ring and retaining ring replacement.

R. D. Vannoy
747/747–400 Fleet Support Chief

NSC:kls

Original: Dated 7 May 1987.

Revision A: Dated 31 March 1989. Revised the Discussion to add additional caused of O–ring damage. Revised Boeing Action to provide updated O–ring/retaining ring replacement interval info and revised illustration info. Revised Suggested Operator Action to provide revised replacement interval recommendations. Added Attachments I, II, and III. Added References e) and f).

Revision B: Revised to include experience with the Fluorosilicone O–rings in the 747–400 application. Revised the Discussion to add information on the Fluorosilicone O–rings. Revised Boeing Action to confirm changes to the Reference c), d) and e) manuals and advise that the Fluorosilicone O–rings will be deleted from the applicable strut fuel line installation drawings. Deleted reference to 747 MT 28–11 and deleted Attachments I, II and III, since the intent of the maintenance tip and attachments has been incorporated into the reference c), d) and e) manuals. Revised suggested operator action to recommend replacement of Fluorosilicone O–rings with the Nitrile O–rings. Added reference f). Added summary.

Appendix 2. Evacuation checklist of TF-ARS

EVACUATION

PARKING BRAKE	SET	C
START LEVERS	CUTOFF	C
EVACUATION	INITIATE	C
TOWER	NOTIFY	F/O
OUTFLOW VALVES (IF REQUIRED).....	OPEN	F/E
ENGINE AND APU FIRE SWITCHES	PULL	F/E
FIRE BOTTLES	DISCHARGE	F/E

EMERGENCY CALL-OUTS AND PROCEDURES

Evacuation

- **"EVACUATE", "EVACUATE"**
- **"OPEN SEATBELTS AND GET OUT", "OPEN SEATBELTS AND GET OUT"**

Flight Crew has decided to evacuate the Airplane and turns on the EVAC signal (as installed) on. Cabin Crew start evacuation immediately.

Emergency situation, e.g: abnormal landing or rejected take-off

- **"CABIN CREW STANDBY", "CABIN CREW STANDBY"**

Flight crew is not injured and is able to react and make decisions

P/A system operative. Further instructions will follow.

Evacuation not necessary

- **"REMAIN SEATED", "REMAIN SEATED"**

Flight Crew finds that no immediate danger exists and therefore an evacuation is not justified.

Cabin Crew keep passengers seated and prepare for normal arrival.

Further procedures on back of this page (page T-4).

Unexpected emergency with no time available

- **"EMERGENCY, EMERGENCY",**
  "GET DOWN, GET DOWN"

Warning from the Flight Crew of an unexpexted emergency with no time for briefing. Cabin crew shout repeatedly:

- **"BEND DOWN", " BEND DOWN"**

Expected Abnormal Landing

At 1.500 feet- two minutes to landing.

- **"CABIN CREW, TAKE YOUR SEAT",**
  "CABIN CREW, TAKE YOUR SEAT"

Cabin Crew take their seat. Pilot Monitoring switches on Emergency Lights.

Alert Call

At 500 feet- 30 seconds to landing.

- **"BRACE, BRACE", "BRACE, BRACE"**

Cabin Crew assume brace position.CCM shout continuously.

- **"BRACE, BRACE".**

Rapid Depressurization

- **"EMERGENCY DESCENT", "EMERGENCY DESCENT"**

The Flight Crew will initiate a steep descent.

Cabin Crew shall take any seat immediately and grab the nearest oxygen mask.

Emergency Descent Complete

- **"CABIN CREW, DESCENT COMPLETED",**
  "CABIN CREW, DESCENT COMPLETED"

The Airplane has levelled off.

Cabin Crew may leave their seats to attend to Passengers needs, wearing portable oxygen.

A priority call indicating: an abnormal or emergency situation, arising or existing

- **"SENIOR TO FLIGHT DECK",**
  "SENIOR TO FLIGHT DECK"

SCCM proceeds immediately to flight deck for briefing.

TTI briefing:

- **Time** available.
- **Type** of landing/**Type** of emergency.
- **Instructions** and extra information available.

PASSENGER EVACUATION

Parking Brake	SET	C
Start Levers	CUTOFF	C
Evacuation	INITIATE	C
Tower	NOTIFY	F/O
Outflow Valves (if Required)	OPEN	F/E
Engine and APU Fire Switches	PULL	F/E
Fire Bottles	DISCHARGE	F/E

Appendix 3, first page of task card 4-28-007-02-3 published by the manufacturer.

STATION | TAIL NO. | DATE

BOEING 747

KSU TASK CARD

MPD/CARD NO. 4-28-007-02-3

AIRLINE CARD NO.

SKILL	WORK AREA	RELATED TASK	INTERVAL	PHASE	MPD REV	TASK CARD REVISION
AIRPL	STRUT 3		7C	18484	001	APR 25/07

TASK	TITLE	STRUCTURAL ILLUSTRATION REFERENCE	APPLICABILITY AIRPLANE	APPLICABILITY ENGINE
REPLACE	STRUT 3 FUEL FEED LINE O-RINGS		ALL	7R4G

ZONES	ACCESS PANELS
470	621AB 652AB

MECH | INSP | MM REFERENCE

REPLACE ALL OF THE STRUT 3 ENGINE FUEL FEED LINE O-RINGS WITHIN THE STRUT. 28-22-07-4A

1. General

A. This procedure provides general information for removal and installation of engine fuel feed system fuel lines and bulkhead fitting. Three coupling types are used: a flexible full coupling, flexible half coupling and a rigid coupling.

B. If line is damaged, the replacement may require that the line be cut into sections for removal and installation due to its length. Therefore, if damage exists to a line that exceeds one rib bay in length, only the damaged section should be replaced, not the entire line.

C. Start connection with a rigid coupling at some fixed point like a bulkhead valve, or pump fitting and observe that last connection point is a flexible full coupling.

D. Do not loosen rigid coupling to facilitate installation of other couplings in the fuel line.

2. Remove the Fuel Line

(1) Purge and go to into the fuel tank (AMM 28-11-00/201).

WARNING: OBEY THE PURGING AND FUEL TANK ENTRY PRECAUTIONS. FAILURE TO OBEY THE PRECAUTIONS CAN CAUSE INJURY OR AN EXPLOSION.

(2) Disconnect the bonding jumpers and keep the jumper clamps for re-installation.

(3) Loosen the coupling nuts and disconnect the fuel line clamps from the structure.

Appendix 4, task card B47-C2-043-500 published by the maintenance division.

ENGINE #3 STRUT

malaysia airlines

VIEW (013-00623)

	REGN	RAISED BY	DATE RAISED	WORK AREA	ATA	CONTROL NO
ROUTINE	TF-ARS	ZALEHAMI	27-08-2007 15:11			623
	SOURCE REF		CHECK		ZONE	CARD NO
			C1C2		430	B47-C2-043-500

TASK DESCRIPTION :
REPLACE ALL OF THE STRUT ENGINE FUEL FEED LINE O-RINGS WITHIN THE STRUT.

CROSS REFERENCE DOCUMENT... (WPL/IRC/MR1/MR2/CC CARD..)	**SYS-01187, SYS-01188**

COMPONENTS(S) / MATERIAL USED

DESCRIPTION	PART NO	SERIAL NO OFF	SERIAL NO ON	BATCH NO	QTY
O RING	AS3578-023			35590 (CUSTOMER SUPPLY)	8 EACH
O RING	MS9021-022			10085 (CUSTOMER SUPPLY)	12 EACH
O RING	69890-119			04584138 (CUSTOMER SUPPLY)	8 EACH

FORM NO : 303077 03/2007 E-PROMIS

Appendix 5. Leak test method 2

(11) On the exterior surface of front spar, apply BMS 5-95 sealant over all of the nut and washer.
(12) From in the fuel tank, to install the engine fuel feed tube, do this task: Install the Fuel Line.
(13) From out of the fuel tank, to install the upper strut engine fuel feed tube, do this task: Install the Fuel Line.
(14) For the inboard tank bulkhead fitting, do these steps:
(a) Install the inboard strut front spar pneumatic T-Duct (AMM 36-11-01/401). To do this, do these steps:
1) Install the coupling assemblies, V-clamp, spring (if applicable), and T-duct.
2) Install the lockwires and seals.
(b) Do a check of the T-duct for leaks (AMM 36-11-01/601).
(15) Make sure that all tools and equipment are removed from tank.
(16) Install the fuel tank access doors (AMM 28-11-01/401, AMM 28-11-02/401).
(17) Refuel the fuel tank (AMM 12-11-01/301) and do a check for leaks.
(18) Do a Leak Check for the Fuel Line in the Strut Area.

NOTE: The purpose of this check is to make sure the fuel line in the strut area is installed correctly. Use one or both methods to leak check the fuel line in the strut area. A fuel pressure leak check is the preferred method, however, it is recommended that both an air pressure leak check and a fuel pressure leak check be done. If METHOD 1 is done first, it will reduce the possibility of a fuel leak and the possible time delay caused by the removal of fuel from the fuel line if maintenance action is necessary to repair a leak.

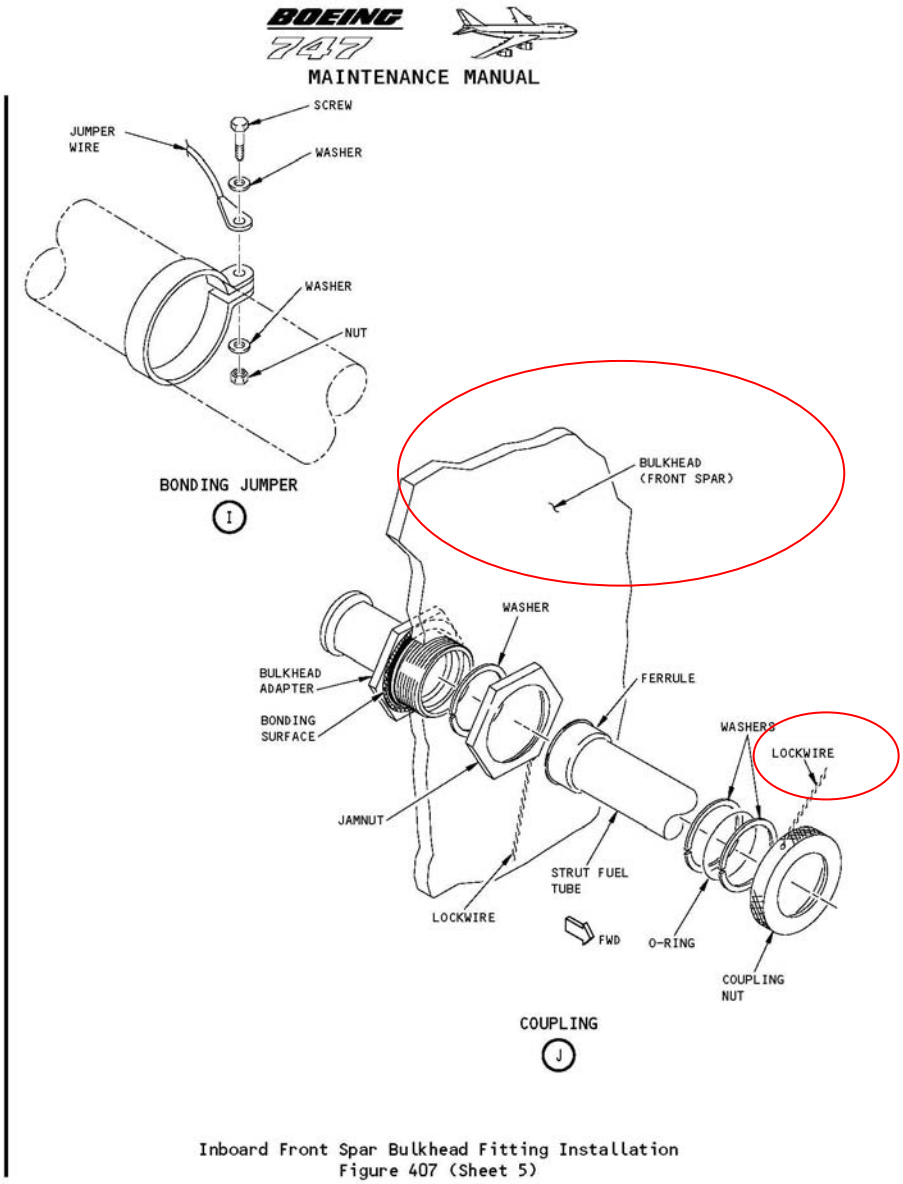
METHOD 1:
Air Pressure Leak Check. This method uses 40 psi air pressure with the fuel spar valve closed to check the fuel line in the strut area for leaks.

METHOD 2:
Fuel Pressure Leak Check. This method uses a visual inspection of the fuel line in the strut area with the fuel spar valve open and the fuel line pressurized with fuel from the fuel tank pumps.

(a) METHOD 1;
Air Pressure Leak Check.
To do this check, do this task: Engine Fuel Feed Lines and Couplings Leak Check (AMM 28-22-07/601).
(b) Method 2;
Fuel Pressure Leak Check;
To do this check, do these steps:
1) Make sure the fuel line from the front spar to the engine pump is completely installed.

Appendix 6. Revised Maintenance Manual.

The aircraft manufacturer made changes to the maintenance manual by adding the bulkhead to the figure in order to avoid mixing rigid coupling with flexible half coupling. Furthermore, the chances to the maintenance manual illustrate the placement of the lock wire.



Inboard Front Spar Bulkhead Fitting Installation
Figure 407 (Sheet 5)