Aircraft Serious Incident Report

One Engine In-Flight Shutdown

Air France

B777-200F, F-GUOB

Incheon International Airport

March 14, 2012

May 15, 2013

AVIATION AND RAILWAY ACCIDENT INVESTIGATION BOARD

This aircraft serious incident report has been prepared in accordance with the Article 25 of the Aviation and Railway Accident Investigation Act of the Republic of Korea.

According to the provisions of the Article 30 of the Aviation and Railway Accident Investigation Act, it is stipulated;

The accident investigation shall be conducted separately from any judicial, administrative disposition or administrative lawsuit proceedings associated with civil or criminal liability.

And in the Annex 13 to the Convention on International Civil Aviation, Paragraphs 3.1 and 5.4.1, it is stipulated as follows:

The sole objective of the investigation of an accident or incident shall be the prevention of accidents and incidents. It is not the purpose of the activity to apportion blame or liability. Any investigation conducted in accordance with the provision of this Annex shall be separate from any judicial or administrative proceedings to apportion blame or liability.

Thus, this investigation report shall not be used for any other purpose than to improve aviation safety.

In case of divergent interpretation of this report between the Korean and English languages, the Korean text shall prevail.

Aircraft Serious Incident Report

Aviation and Railway Accident Investigation Board, *One engine In-flight Shutdown, Air France, B777-200F, F-GUOB, Incheon International Airport, March 14, 2012*. Aircraft Serious Incident Report ARAIB/AIR-F1201, Sejong Special Self-governing City, Republic of Korea.

The Aviation and Railway Accident Investigation Board (ARAIB), Republic of Korea, is a government organization established for independent investigation of aviation and railway accident, and the ARAIB conducts accident investigation in accordance with the provisions of the Aviation and Railway Accident Investigation Act of the Republic of Korea and Annex 13 to the Convention on International Civil Aviation.

The objective of the investigation by the ARAIB is not to apportion blame or liability but to prevent accidents and incidents.

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One Engine In-flight Shutdown

- Operator: Air France
- Manufacturer: The Boeing Company
- Type: B777-200F
- Registration Mark: F-GUOB
- Location: Incheon International Airport
- Date & Time: March 14, 2012, about 15:40 (Korean Standard Time[1])

Synopsis

On March 14, 2012, about 15:40, Air France flight 6775 (freighter, ICN/CDG, B777-200F, F-GUOB) returned to Incheon International Airport since the right engine (#2 engine) N1 failed to reach N1 command approximately five minutes after takeoff, and during landing, "ENGINE FAIL R" warning message was displayed at 100 feet.

The Aviation and Railway Accident Investigation Board (ARAIB) determines that the cause of this serious incident was 「As the interstage strainer was contaminated by metal chips generated by foreign object ingestion, gear set was damaged, which caused low fuel pressure, and as fuel pressure got lower, fuel was not supplied to the engine, thereby resulting in one engine in-flight shutdown.」

The ARAIB issued one safety recommendation to Air France, operator of the aircraft, as a result of the serious incident investigation.

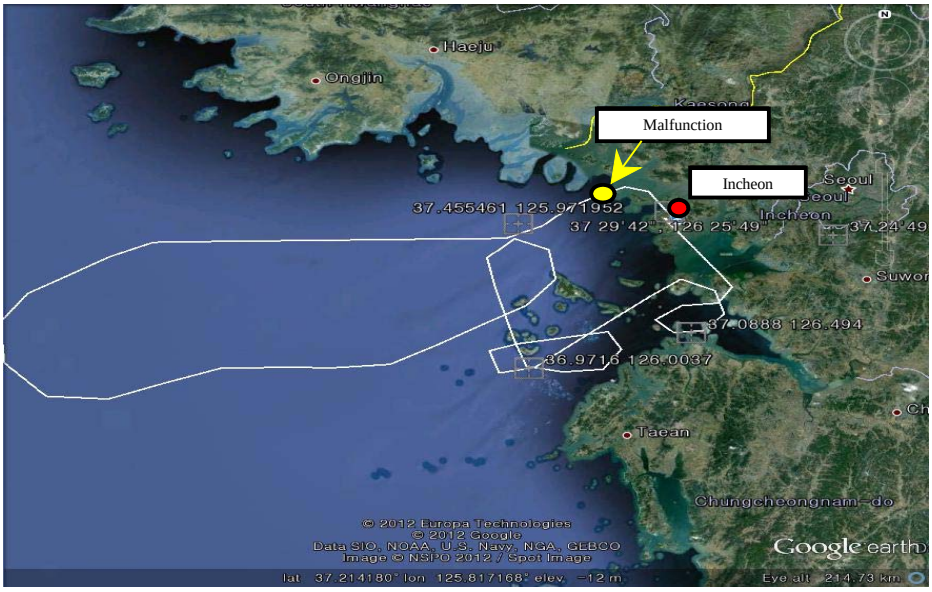
1) Unless otherwise indicated, all times in this report are Korean Standard Time (GMT+9).

1. Factual information

1.1 History of the Flight

On March 14, 2012, at 15:22, Air France flight 6775 (hereafter referred to AF6775) (freighter, ICN/CDG, B777-200F, F-GUOB) took off from runway at Incheon International Airport and flew in accordance with Standard Instrument Departure (SID). Approximately four minutes after takeoff (at 15:26), "ENG THRUST R[2)] (Engine Thrust Right)" advisory message was displayed at a pressure altitude of 9,600 feet, 96 miles west of Incheon International Airport (hereafter referred to Incheon Airport).

Due to the event, the captain decided to divert to Incheon Airport, and while dumping fuel to reduce landing weight, he determined that the right engine malfunctioned and accordingly, declared an emergency and landed at Incheon Airport. During landing, "ENG FAIL R (Engine Fail Right)" warning message was displayed at a radio altitude of 121 feet. The flight route and the sequence of major events during flight are shown in [Figure 1] and [Table 1], respectively.



[Figure 1] Flight Route

2) The message is displayed when the engine delivers less thrust than commanded.

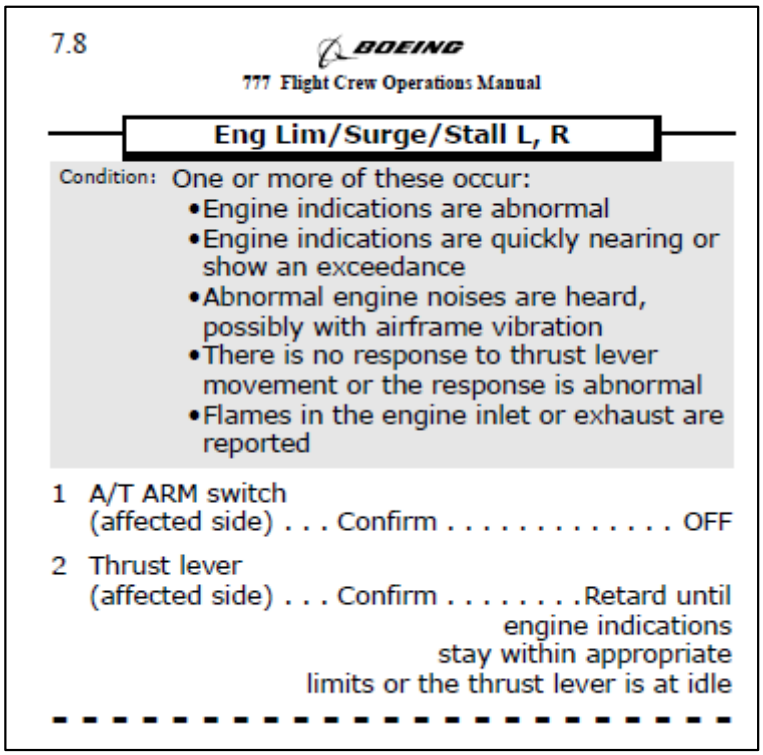
Time	Major Events During Flight
15:22:40	The Captain took off and flew in accordance with SID, Nopik 1B.
15:26:52	At a pressure altitude of 9,600 ft, "ENG THRUST R[3)]" advisory message was displayed.
15:31:13	AF6775 was transferred from SEL DEP to ICN ACC. It obtained a clearance to climb up to 23,600 ft (7,200 m) on 132.8 Mhz.
15:38:40	The flight crew informed ICN ACC that AF6775 might need to hold before entering China since it might divert due to engine malfunction.
15:41:09	AF6775 requested a diversion to Incheon Airport while approaching waypoint GONAV[4)]. ICN ACC provided the flight with heading for direct ARIVA[5)].
15:41:38	The flight crew notified ICN ACC of "PAN PAN PAN[6)]" situation and engine malfunction.
15:44:38	The flight crew notified ICN ACC of the need for fuel dump area.
15:50:30	The flight crew requested fuel dumping while descending.
15:51:46	AF6775 was transferred to SEL APP of 119.75 Mhz, then to 121.35 Mhz.
15:59:33	Fuel dumping commenced (fuel quantity was 89,000 lbs).
16:16:59	The flight crew commenced engine limit/surge/stall procedures.
16:22:03	The flight crew completed engine limit/surge/stall procedures.
16:22:32	Fuel dumping ended (fuel quantity was 19,900 lbs).
16:12:26	Determining engine malfunction, the flight crew declared "Mayday Mayday Mayday[7)]" and requested runway 34 at Inchon Airport.
16:26:28	SEL APP cleared AF6775 for an ILS approach to runway 34.
16:29:14	AF6775 was switched to ICN Airport Control.
16:29:36	ICN Airport Control cleared AF6775 for landing on runway 34 at Incheon Airport.
16:31:47	The flight crew disengaged the autopilot and manually flew the aircraft at a pressure altitude of 430 ft.
16:32:19	"ENG FAIL R (Engine Fail Right)" warning message was displayed at a radio altitude of 121 feet.
16:32:30	AF6775 touched down runway and taxied for itself.

[Table 1] Sequence of Major Events During Flight

3) The message is displayed when the engine delivers less thrust than commanded.
4) A point 96 NM west of Incheon Airport or a point on airway G597, 20 NM from Shanghai FIR, China.
5) A point on airway Y64, 38 NM west of Incheon Airport.
6) A word referred to a state of urgency in radio communications.
7) An emergency procedure word used internationally as a distress signal in radio communications.

1.1.1 Emergency Actions Taken by the Flight Crew

From 16:16:59 until 16:22:03, the flight crew, after discussion, performed engine limit/surge/stall procedures in the quick reference handbook (QRH). In accordance to the procedures, the auto throttle was supposed to be off, but the flight crew kept it on. They used 20 degrees of flaps during landing.



7.8

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777 Flight Crew Operations Manual

Eng Lim/Surge/Stall L, R

Condition: One or more of these occur:

- Engine indications are abnormal
- Engine indications are quickly nearing or show an exceedance
- Abnormal engine noises are heard, possibly with airframe vibration
- There is no response to thrust lever movement or the response is abnormal
- Flames in the engine inlet or exhaust are reported

1 A/T ARM switch
(affected side) . . . Confirm . . . . . OFF

2 Thrust lever
(affected side) . . . Confirm . . . . . .Retard until engine indications stay within appropriate limits or the thrust lever is at idle

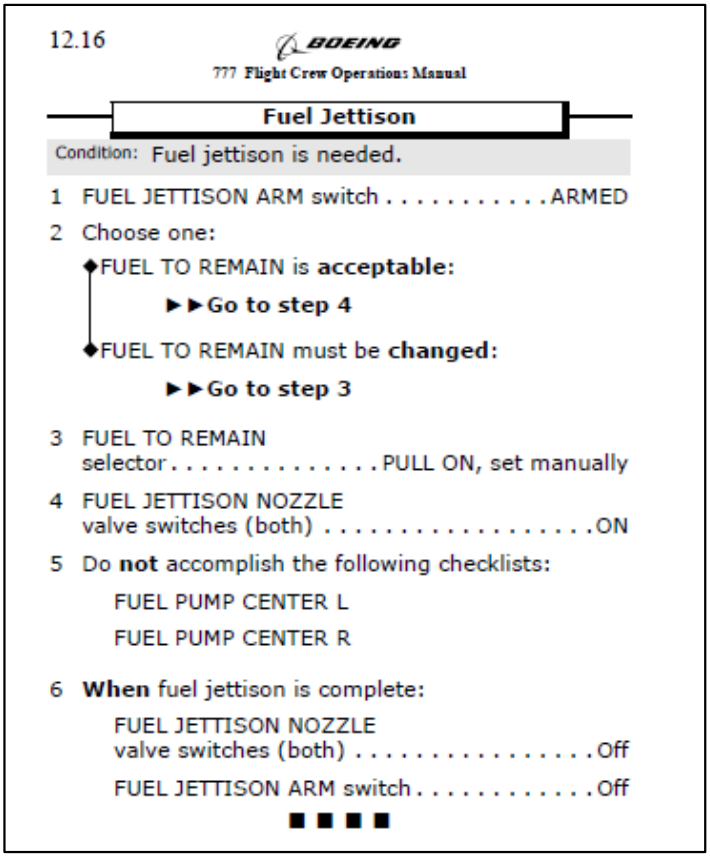
[Figure 2] Engine Limit/Surge/Stall Procedures

The flight crew decided to divert to Incheon Airport due to the right engine malfunction and requested the Incheon area control center (ICN ACC) to give them radar vector to the fuel dump area[8] to reduce landing weight.

According to the FDR data, the captain initiated fuel dumping at a pressure altitude of 10,700 feet when the quantity of fuel was 89,000 lbs (40.4 tons) and

8) Seoul TMA Fuel Dump Area: Area within a 5-NM radius of a point 22 NM west of Incheon VOR (NCN R264/D22) or a point 45 NM west of Anyang VOR (SEL R278/D45) at 6,000 feet and over.

completed it at a pressure altitude of 6,700 feet when the quantity of fuel was 19,900 lbs (9.03 tons). AF6775 jettisoned approximately 31 tons of fuel since it set its new landing weight at 260 tons.



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Fuel Jettison

Condition: Fuel jettison is needed.

1 FUEL JETTISON ARM switch . . . . . .ARMED

2 Choose one:

◆FUEL TO REMAIN is **acceptable:**

►►**Go to step 4**

◆FUEL TO REMAIN must be **changed:**

►►**Go to step 3**

3 FUEL TO REMAIN
selector . . . . . .PULL ON, set manually

4 FUEL JETTISON NOZZLE
valve switches (both) . . . . . .ON

5 Do **not** accomplish the following checklists:

FUEL PUMP CENTER L

FUEL PUMP CENTER R

6 **When** fuel jettison is complete:

FUEL JETTISON NOZZLE
valve switches (both) . . . . . .Off

FUEL JETTISON ARM switch . . . . . .Off

■ ■ ■ ■

[Figure 3] Fuel Jettison Procedures

1.2 Injuries to Persons

Injuries	Crew	Passenger	Other
Fatal	0	0	0
Serious	0	0	0
Minor/None	0	0	0

1.3 Damage to Aircraft

There was no damage to the airframe, but damage to the system and components was described in 1.12 Wreckage and Impact Information of this report.

1.4 Other Damage

None

1.5 Personnel information

1.5.1 The Captain

The captain (male, age 52) held a valid air transport pilot certificate[9], a B777 type rating[10], a first-class airman medical certificate[11], an aircraft radio operator license,[12] and ICAO English Proficiency Certificate[13]. The captain had accumulated 12,227 total flight hours, including 4,887 hours as pilot-in-command and 2,212 hours in B777 airplanes as pilot-in-command. He had flown 118 and 38 hours in the 90 and 30 days, respectively, before the serious incident.

He received his recurrent simulator training on November 26, 2011 and passed his proficiency check on November 27, 2011 and line check on September 5, 2011.

The captain had Air France flight 264 (CDG-ICN) on March 11 (Sun), 2012 and the next day on March 12 (Mon), landed at Incheon Airport and took a rest

9) Certificate No.: F-LAA00023423 (valid until Jan. 4, 2016).
10) Term of Validity: Nov. 27, 2011 - Jan. 31, 2013.
11) Term of Validity: Sep. 19, 2011 - Sep. 30, 2012.
12) License No.: QRI 15517.
13) Expiration Date: May 31, 2016.

at a hotel. On March 13 (Tue), he got up at 08:00 and spent time exercising and shopping and at 22:30, went to bed. On March 14 (Wed), he got up at 07:00 and had Air France flight 6775.

The captain stated that he did not drink any alcohol or take any illegal medication in the 24 hours before the serious incident flight and was in good health.

1.5.2 The Co-pilot

The co-pilot (male, age 46) held a valid air transport pilot certificate[14], a B777 type rating[15], a first-class airman medical certificate[16], an aircraft radio operator license, and ICAO English Proficiency Certificate[17]. He had accumulated 7,735 total flight hours, including 4,350 hours in B777 airplanes. He had flown 132 and 39 hours in the 90 and 30 days, respectively, before the serious incident.

The co-pilot received his recurrent simulator training on December 8, 2011 and passed his proficiency check on December 9, 2011.

The co-pilot had Air France flight 264 (CDG-ICN) on March 11 (Sun), 2012 and the next day on March 12 (Mon), landed at Incheon Airport and took a rest at a hotel. On March 13 (Tue), he got up at 07:00 and spent time reading books and at 23:30, went to bed. On March 14 (Wed), he got up at 07:30 and had Air France flight 6775.

The co-pilot stated that he did not drink any alcohol or take any illegal medication in the 24 hours before the serious incident flight and was in good

14) Certificate No.: F-LAA00030083 (valid until Nov. 8, 2015).
15) Term of Validity: Jul. 11, 2011 - Aug. 31, 2012.
16) Term of Validity: May 23, 2011 - Jun. 30, 2012.
17) Expiration Date: Oct. 31, 2016.

health.

1.5.3 The Observer/Co-pilot

The observer/co-pilot (male, age 43) held a valid air transport pilot certificat e,[18] a B777 type rating[19], a first-class airman medical certificate[20], an aircraft radio operator license, and ICAO English Proficiency Certificate[21]. He had accumulated 8,550 total flight hours, including 6,550 hours in B777 airplanes. He had flown 130 and 44 hours in the 90 and 30 days, respectively, before the serious incident.

The observer/co-pilot received his recurrent simulator training on January 5, 2012 and passed his proficiency check on January 6, 2012.

The observer/co-pilot had Air France flight 264 (CDG-ICN) on March 11 (Sun), 2012 and the next day on March 12 (Mon), landed at Incheon Airport and took a rest at a hotel. On March 13 (Tue), he got up at 08:00, spent time taking a walk and shopping, had dinner, then went to bed at 23:00. On March 14 (Wed), he got up at 07:00 and had Air France flight 6775.

The observer/co-pilot stated that he did not drink any alcohol or take any illegal medication in the 24 hours before the serious incident flight and was in good health.

18) Certificate No.: F-LAA00056141 (valid until Mar. 17, 2016).
19) Term of Validity: Jan. 6, 2012 - Feb. 28, 2013.
20) Term of Validity: Apr. 12, 2012 - Apr. 30, 2012.
21) Expiration Date: May 31, 2016.

1.6 Aircraft Information

1.6.1 Airworthiness and Maintenance

1.6.1.1 Aircraft General

The affected aircraft registered as F-GUOB was a B777-200F airplane manufactured by the Boeing Company in the United States and delivered to Air France on February 24, 2009. The aircraft received the certificate of airworthiness from the French airworthiness authorities on February 27, 2009 and remained airworthy by receiving a current airworthiness review certificate[22] in accordance with Commission Regulation. The aircraft history and specifications are shown in [Table 2] and [Table 3], respectively.

Nationality & Registration Mark	F-GUOB	Type Rating No.	T00001SE
Airplane	Multi-engine Landplane	Manufacturer	The Boeing Company
Airworthiness Category	Large Airplane	Aircraft Serial No.	32965
Airworthiness Certificate No.	119342	Airworthiness Certificate Issue Date	2009.2.27.
Airworthiness Review Certificate Term of Validity	Dec 16, 2011 - Dec 16, 2012	Engine Type	GE90-110B
Registration Certificate Issue Date	2011.10.28	Engine Serial No.	906544

[Table 2] Aircraft History

22) It proves that the aircraft airworthiness is continuing and valid in accordance with Commission Regulation (EC). Term of validity: Dec. 16, 2011 - Dec. 16, 2012.

Category	Airplane	Max. Takeoff Weight	347.8 ton
Type	B777-200F	Max. Zero Fuel Weight	248.1 ton
Airworthiness Category	Large Airplane	Empty Weight	141.1 ton
Endurance	9:44	Fuel Load	181,283 ℓ
Landing Roll Distance	1,773 m	Airspeed Limit	0.96 mph
Max. Cargo (Payload)	107 ton	Cruising Speed	0.84 mph
Fuel Consumption	19,944 lb/hr	Takeoff Roll Distance	3,440 m
Max. Operating Altitude	43,100 ft	Range	8,821 km

[Table 3] Major Aircraft Specifications

1.6.1.2 Aircraft Maintenance History

On March 12 and 13, before the serious incident, the main fuel pump of the aircraft was overhauled and replaced due to fuel drain leakage. As all the parameters proved to be normal after the engine run-up, the aircraft was released for flight.

On March 14, after takeoff from Incheon Airport, the right engine N1 did not reach N1 command[23], and "ENG THRUST R" advisory message was displayed. The flight crew turned on and off the auto throttle but to no avail and thus, decided to divert. While approaching, "ENG FAIL R" warning message was displayed, and one engine shut down at 100 feet, but AF6775 landed with one engine.

On March 14, 2012, Air France sent its maintenance team, tooling and replacement components to Incheon Airport, and on March 15, inspected the

23) N1 command was 89.8%, but 84.1% of N1 was achieved.

interstage strainer installed in the main fuel pump. One bolt was found between the strainer and the housing. The bolt was embedded in the strainer screen.

On March 15, for troubleshooting, the fuel filter, main fuel pump, and hydro-mechanical unit (HMU) were replaced, but as a result of the idle run test of the engine, few metal particles were detected. The fuel filter was replaced again, and the takeoff run test was performed. As a result, less than 10 very thin particles were detected and thus, the aircraft was sent to Paris-Charles de Gaulle Airport.

On March 16, Air France additionally replaced the lube/servo fuel/oil cooler[24] and IDG fuel/oil cooler due to fuel contamination during the event.

1.6.1.3 Related Component History

Component	Part No.	Serial No.	Time Since New	Cycle Since New	Time Since Overhaul	Cycle Since Overhaul
Main Fuel Pump	838000-2	ATC95078	28,629	3,130	14	3
HMU	8061-693	WYGB8651	14,108	1,957	14,108	1,957
Lube-Servo Fuel/Oil Cooler	UA541461-14	UDDC0966	14,919	2050	14,919	2050
IDG Fuel/Oil Cooler	UA541464-6	UDDP0574	1,003	156	1,003	156

[Table 4] Details and Service Time of Affected Components

1.6.1.4 Weight and Balance

The weight and balance data of AF6775 are as follows:

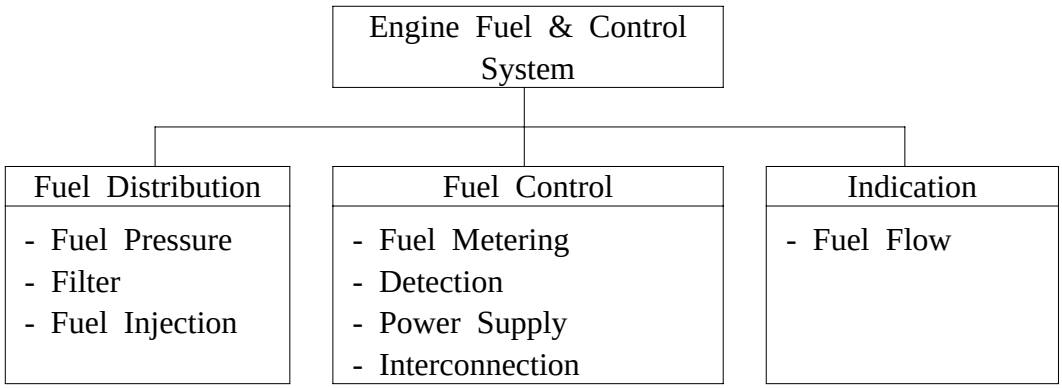
24) Lube and cooler can be replaced with main and heat exchanger, respectively. It is one assembly, which is functionally categorized as the main fuel/oil cooler and servo fuel/oil cooler.

Takeoff Weight (TOW): 311,815 kg	Max. Takeoff Weight (MTOW): 347,451 kg
Zero Fuel Weight (ZFW): 216,945 kg	Max. Zero Fuel Weight (MZFW): 248,115 kg
Estimated Landing Weight (ELDW): 225,815 kg	Max. Landing Weight (MLDW): 260,815 kg
Takeoff Weight Center of Gravity (TOWCG): 29.16%	Zero Fuel Weight Center of Gravity (ZFWCG): 28.20%

1.6.2 Aircraft System

1.6.2.1 Engine Fuel and Control System

As shown in [Figure 4], the engine fuel and control system is composed of 3 subsystems: fuel distribution, fuel control, and indication. The fuel distribution system consists of fuel pressure, fuel filter, and fuel injection. The fuel control system is comprised of fuel metering, detection, power supply, and interconnection. The indication system is an indicator showing fuel flow.



[Figure 4] Engine Fuel and Control System

The main fuel pump pressurizes fuel supplied by the airplane fuel system, then sends it through the lube/servo and IDG fuel/oil coolers[25]. The fuel flows

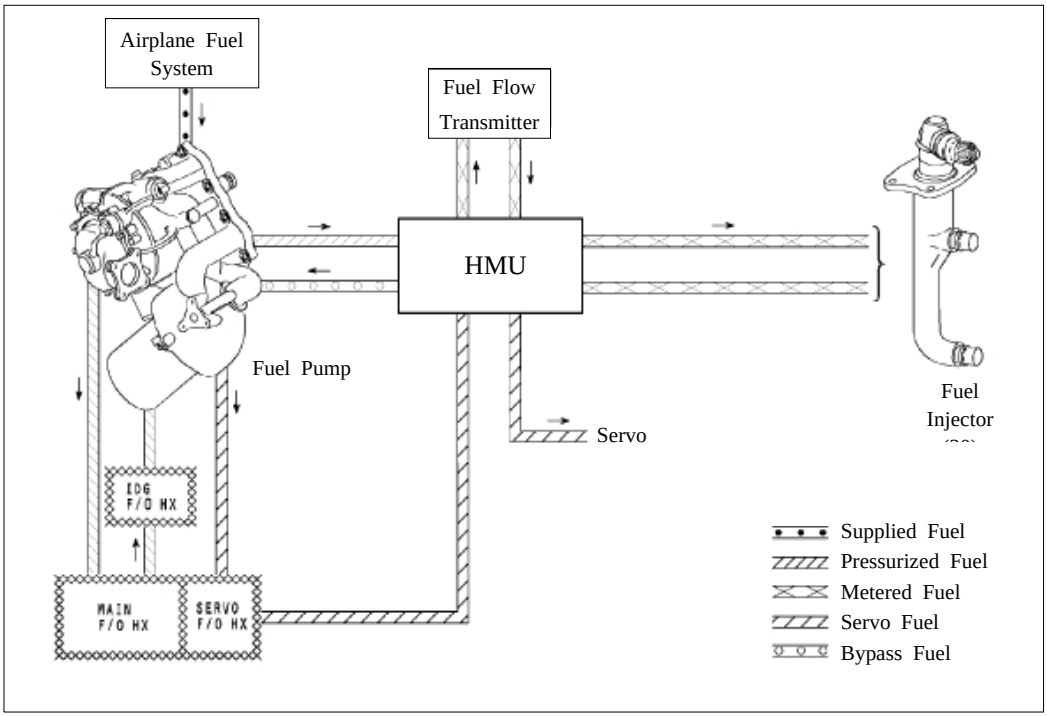
25) The fuel/oil cooler increases the temperature of fuel and decreases the temperature of oil.

back to the pump where it goes through the fuel filter element.

After the fuel goes through the fuel filter element, it goes to the HMU. The HMU meters the fuel. The fuel goes from the HMU, through the fuel flow transmitter, then back into the HMU. The HMU distributes the fuel into two fuel supply manifolds. The supply manifolds send the fuel to 30 fuel nozzles.

The HMU gets more fuel from the pump than the engine needs. The fuel that the HMU does not use goes back to the main fuel pump. This fuel is called bypass fuel.

Downstream from the fuel filter, a small amount of fuel also goes to the servo fuel/oil cooler then to the HMU. The servo fuel/oil cooler increases the temperature of the servo fuel before it goes to the HMU. The schematic diagram of the engine fuel system is shown in [Figure 5].



[Figure 5] Engine Fuel System

1.6.2.2 Main Fuel Pump

The main fuel pump pressurizes and cleans fuel from the airplane fuel system[26]. It is on the aft face of the gearbox. The pump has external and internal connections for fuel flow.

The fuel pump is a two-stage pump. The main gearbox turns the pump. The pump has an external connection for fuel from the airplane tanks. The other fuel flow into and out of the pump is through the fuel adapter on the gearbox that is not shown from the outside.

The pump has an inlet drain plug. When this plug is removed, you can access the strainer between the two pump stages and drain fuel from the pump.

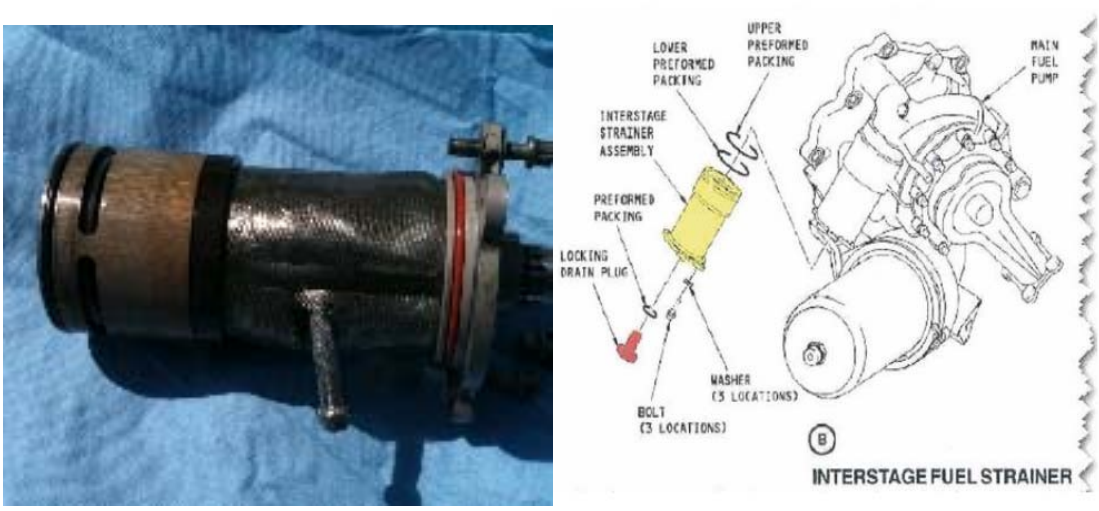
The fuel filter has three parts: housing, filter element, and bypass valve. The filter housing is removed to change or inspect the filter element. The filter housing has a ratchet lock. To remove the housing, you must push the ratchet lock while turning the housing. Before removing the housing, the fuel from the housing should be drained with the drain plug.

The fuel manifold pressure sensor is mounted on the forward side of the HMU. This sensor provides the fuel pressure in the HMU manifold 2. The EEC uses this information for fuel system fault monitoring. The fuel pump has a fuel filter differential pressure sensor on the aft end of the main fuel pump just above the filter bowl.

As shown in [Figure 6], when the ARAIB inspected the main fuel pump interstage strainer shortly after the serious incident, one bolt was embedded in the strainer screen, and many metal chips were found in the screen. It was

26) Distinct from the engine fuel system, the airplane fuel system is in charge of fuel supplied from the airplane fuel tank to the engine fuel pump.

confirmed that the bold was used to install the main fuel pump on the bench support plate.



[Figure 6] Interstage Strainer and Bolt

1.6.2.3 Hydro-Mechanical Unit (HMU)

The electric engine control[27] (EEC) controls valves in the HMU to supply metered fuel flow to the engine and to distribute fuel to the fuel nozzles. The valves are as follows: fuel metering valve (FMV); bypass valve (BPV); engine fuel shutoff valve (SOV); and staging valve (SV).

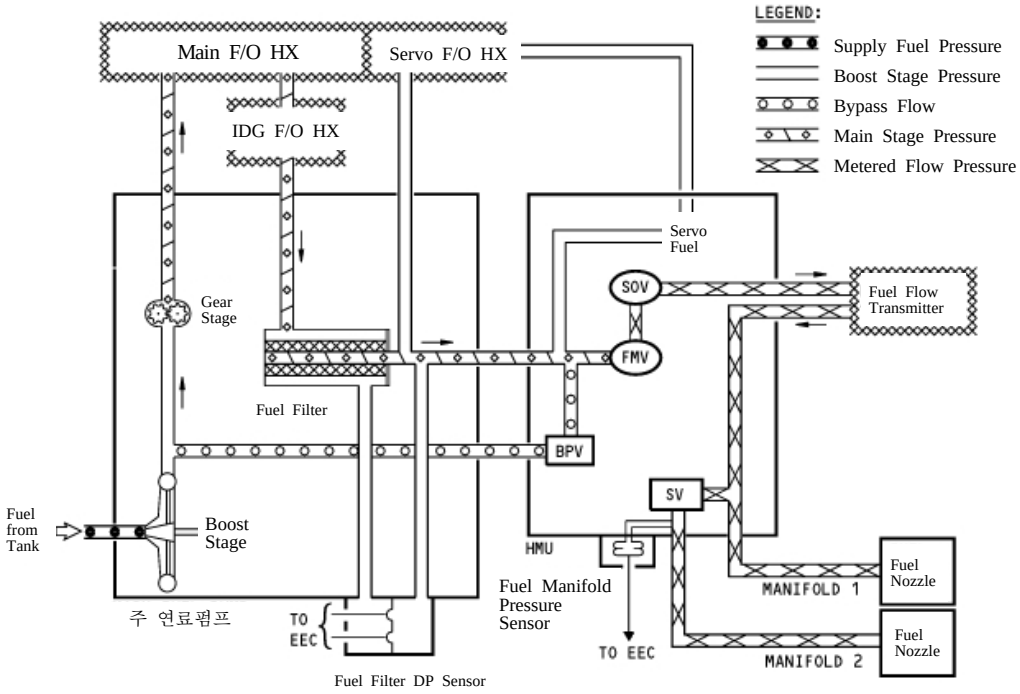
The FMV controls the quantity of fuel that flows into the engine combustor. The BPV sends fuel, which does not have to go to the combustor, to the pre-gear stage. The engine fuel shutoff valve opens for fuel to be supplied to the combustor, and the fuel that passed the engine shutoff valve flows into the fuel flow sensor.

The EEC controls torque motors in the HMU. The HMU gives the EEC feedback about valve and torque motor positions and supplies servo fuel to

27) The computer, which controls electronically the engine thrust as commanded by the pilots, monitors all sensors, diagnose its own defects, and provides fuel quantity signals to the HMU.

operate engine air system actuators.

The HMU supplies fuel to manifold 1 and 2. The SV controls fuel to the manifold 2. The two manifolds supply fuel to 30 fuel nozzles. Fuel is supplied to 20 nozzles through the manifold 1 and 10 nozzles through the manifold 2, respectively. The engine fuel distribution by function is shown in [Figure 7].



Glossary	
Abbreviation	Terminology
IDG	integrated drive generator
EEC	electronic engine control
FMV	fuel metering valve
SOV	shut off valve
BPV	bypass valve
SV	staging valve

[Figure 7] Engine Fuel Distribution by Function

1.6.2.4 Fuel/Oil Cooler

The fuel/oil cooler is composed of the lube[28]-servo fuel/oil cooler and IDG

fuel/oil cooler. The lube-servo fuel/oil cooler is one assembly, which decreases the temperature of lube and servo oil and increases the temperature of fuel to prevent the congelation of fuel. The lube fuel/oil cooler contains stainless tubes and the baffle[29] heat exchanger. It has two fuel tubes and one oil tube, each of which has a bypass valve.

Oil flows around these two fuel tubes, which makes oil heated. The fuel and oil bypass valves permit fule and oil to bypass the core in the event of a blockage, respectively.

The IDG fuel/oil cooler decreases the temperature of oil used in the IDG and increases the temperature of fuel.

1.7 Meteorological Information

Weather observations made by the Korea Meteorological Administration in Gimpo Airport showed that the weather was good with west wind 6.4 m/sec at 260° and temperature 6.1°C.

1.8 Aids to Navigation

No problems with any navigational aids were reported.

1.9 Communications

The flight crew communicated with the air traffic controllers and the airline maintenance center via short-range radio and satellite communication systems, respectively. These two systems were in normal operation.

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28) It indicates the engine oil tank and can be replaced with the term "main." Also, it means the main fuel, distinct from the servo fuel.

29) A flow-directing panel located in front of the outlet, which filters residues.

1.10 Aerodrome Information

Runway 34 at Incheon Airport is 4,000 meters long and 45 meters wide. Its touch-down zone is at an altitude of 7 meters (22.9 feet) on a true heading of 324.67° with the CAT Ⅲ aviation lighting system.

1.11 Flight Recorders

1.11.1 Flight Data Recorder

AF6775 was equipped with the solid-state flight data recorder[30] (FDR) manufactured by Honeywell. On March 14, the recorder was recovered from the site.

The recorder sustained no external damage. The ARAIB retrieved from the FDR the final 25 hours of data and from this raw data, came up with 1,300 parameter values for 1 hour and 45 minutes, including the moment of the serious incident.

1.11.2 Cockpit Voice Recorder

AF6775 was equipped with the solid-state cockpit voice recorder[31] (CVR) manufactured by Honeywell. On March 14, the recorder was recovered from the site.

The ARAIB retrieved four channels of audio data. The files recorded the final 120 minutes of data, including the moment of the serious incident.

30) Part No.: 980-4700-042, Serial No.: SSFDR-18581.
31) Part No.: 980-6022-001, Serial No.: CVR120-12022F.

1.12 Wreckage and Impact Information

For troubleshooting, the maintenance technicians of Air France dispatched from the headquarters in France replaced the following 4 related parts: the main fuel pump; the HMU; the lube-servo fuel/oil cooler; and the IDG fuel/oil cooler.

A foreign object, bolt, was injected into the main fuel pump interstage strainer and worn down, thereby generating many metal chips in the filter, which contaminated fuel. As a result, the main fuel pump and the lube-servo fuel/oil cooler were determined beyond physical repair and scrapped.

The HMU and the IDG fuel/oil cooler were not contaminated by metal particles and thus, were repaired and reused.

1.13 Medical and Pathological Information

Medical and pathological aspects that could have affected the flight crew's performance were not found.

1.14 Fire

No fire occurred as a result of this serious incident.

1.15 Survival Aspects

No search and rescue activities were performed as a result of this serious incident.

1.16 Tests and Research

The ARAIB used the energy dispersive spectrometer to perform an elemental analysis of the bolt found in the interstage strainer, the fuel filter, and 4 metal chips collected from the fuel filter. The result is shown in [Table 6], and the detected elements are ticked.

Element	Aluminum	Chromium	Iron	Nickel	Copper	Tin	Lead
Bolt	√	√	√	√			
Filter		√	√	√			
Metal Chip #1	√				√		
Metal Chip #2					√	√	√
Metal Chip #3	√	√	√	√			
Metal Chip #4	√				√		

[Table 5] Elemental Analysis Result

Also, the infrared spectrometer was used to examine whether proper fuel was used and the moisture content of the sample. The result showed that the sample had a similarity of more than 85% to the elements of Jet-A1.

1.17 Organization and Management Information

Not applicable.

1.18 Additional Information

Not applicable.

1.19 Useful or Effective Investigation Techniques

Not applicable.

2. Analysis

2.1 General

The EEC calculates the accurate quantity of fuel to generate the thrust commanded by the flight crew and supplies the data on the metered quantity of fuel to the HMU. The HMU, according to the instruction of the EEC, adjusts the inner valve and sends the metered fuel to the fuel nozzles.

The main fuel pump pressurized fuel to maintain the fuel flow. The interstage strainer is installed in the fuel pump to prevent fuel contamination.

Initially, the main fuel pump interstage strainer was contaminated by foreign objects, and the contaminated oil went to the fuel/oil cooler and the HMU. Then, the fuel filter was contaminated. In this case, fuel could have flown to the HMU through the bypass return duct, but as fuel supply was not enough due to low fuel pressure caused by the fuel pump failure, the engine shut down.

2.2 Flight Crew Performance

When the "ENG THRUST R" message was displayed, the captain referred to the minimum equipment list (MEL) since there were no particular procedures for the event. After discussion with other pilots, he decided to keep on using the right engine since its indication did not exceed its operational limits.

Yet, he was supposed to turn off the A/T ARM switch according to engine limit/surge/stall procedures in the QRH, but he kept it on.

It is determined that the flight crew performed proper procedures since the right engine's parameters recorded in the FDR did not exceed the operating

limits of GE90-110B as shown in [Table 6].

GE90-110B Engine Parameter (Unit)	Engine Operational Limits	Right Engine Parameter During Flight (Max. - Min.)
N1 RPM (% rpm)	110.5	92.6 - 10.9
N2 RPM (% rpm)	121	110.9 - 27.1
Exhaust Gas Temperature (°C)	1,050	890 - 207
Oil Pressure (psi)	Min. 10	87 - 46
Engine N1 Vibration (scalar)	4.0	1.05 - 0
Engine N2 Vibration (scalar)	4.0	0.1 - 0.83

[Table 6] Engine Parameters Recorded in the FDR

2.3 Aircraft

2.3.1 Analysis of the Engine Fuel System

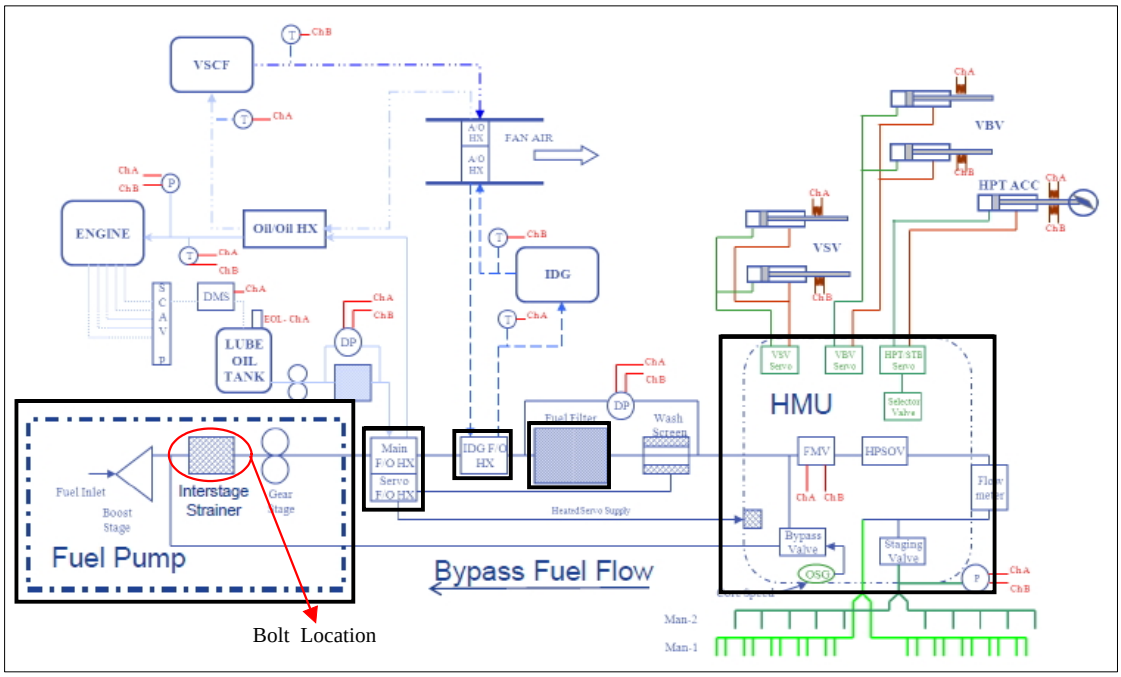
The schematic diagram of the engine fuel system is shown in [Figure 8]. The bolt was embedded in the metal screen of the interstage strainer, fuel filter between boost stage and gear stage of the fuel pump. Many metal chips were also found in the fuel filter.

The ARAIB analysis lab analyzed the bolt and the metal chips. The analysis revealed that the elements of the metal chips were similar to those of the bolt and the strainer gear. Thus, it is determined that the metal chips were generated when the bolt was abraded in the fuel pump and damaged the interstage strainer.

As the main fuel pump interstage strainer was contaminated by metal chips, the next stages of the fuel pump, lube-servo fuel/oil cooler, IDG fuel/oil cooler, and fuel filter were also subsequently contaminated.

The schematic diagram of the engine fuel system is shown in [Figure 8]. The following parts in black rectangles in the figure were replaced for

troubleshooting: fuel pump; lube-servo fuel/oil cooler; IDG fuel/oil cooler; fuel filter; and the HMU. As metal chips were filtered by the fuel filter, the wash screen and the HMU installed aft of the fuel filter were not contaminated.



Glossary		
Abbreviation	Terminology	Explanation
AO HX	air oil heat exchanger	
ch A	channel A	input channel A of the EEC
ch B	channel B	input channel B of the EEC
DMS	debris monitoring system	contaminants (small metal chips, etc.) monitoring system
DP	differential pressure	
FMV	fuel metering valve	
HPSOV	high pressure shut off valve	
HPT ACC	high pressure turbine active clearance control	
IDG	integrated drive generator	
Man	manifold	fuel manifold
OIL OIL HX	oil/oil heat exchanger	
OSG	over speed governor	
P	pressure	pressure sensor
SCAV P	scavenge pump	
SV	staging valve	
T	temperature	temperature sensor
VBV	variable bleed valve	
VSCF	variable speed constant frequency	
VSV	variable stator vane	

[Figure 8] Engine Fuel System

2.3.2 Analysis of the Related Components

2.3.2.1 Main Fuel Pump

There was no external damage to the main fuel pump, and gears turned freely. Also, shafts, lube flow screen, and bearing plate sustained no damage. As shown in [Figure 9] Inspection of the Fuel Pump, a large bolt found between the housing and the strainer during the fuel pump replacement perforated the strainer, and the material of the perforated section was missing.

[Figure 9] Inspection of the Fuel Pump

There was no damage to the inducer, impeller, and inlet housing, but the gear set was damaged to the point of being very difficult to disassemble. The fuel pump failed to pressurize fuel normally due to damage, which caused abnormal fuel supply to the engine. The operator scrapped the fuel pump.

2.3.2.2 HMU

The HMU was disassembled for examination. The examination revealed that the differential pressure check valve was in good condition with nothing else significant found as shown in [Figure 10].

This indicated that the HMU was not contaminated.

The HMU uses servo fuel to operate the fuel metering valve, but it is determined that it sent less fuel than commanded by the flight crew to the fuel nozzles since the fuel pump failed to supply normal servo fuel.

[Figure 10] Differential Pressure Check Valve

2.3.2.3 Lube-Servo Fuel/Oil Cooler

The inspection by a part manufacturer, Triumph Thermal, revealed that some

metal chips were indeed found in the servo in port as shown in [Figure 11]. The boroscope inspection showed that all tubes internally on the servo side of the unit were completely plugged with metal chips.

[Figure 11] Fuel/Oil Cooler Contamination

The operator was unable to remove any of these contaminants since they were packed in the tubes. To remove them, the company attempted various methods such as power flushing, vacuuming, and air pressure and vibration but to no avail.

The lube-servo fuel/oil cooler was scrapped since it was determined beyond physical repair. The unit was internally contaminated by metal chips. As the tubes were internally plugged with metal chips, the internal damage to the tubes could not be determined.

2.3.2.4 IDG Fuel/Oil Cooler

The inspection by the manufacturer revealed that the IDG fuel/oil cooler was in good condition and not contaminated by metal chips.

2.3.3 Elemental Analysis

[Table 5] Elemental Analysis Result showed that metal chip #3 was generated

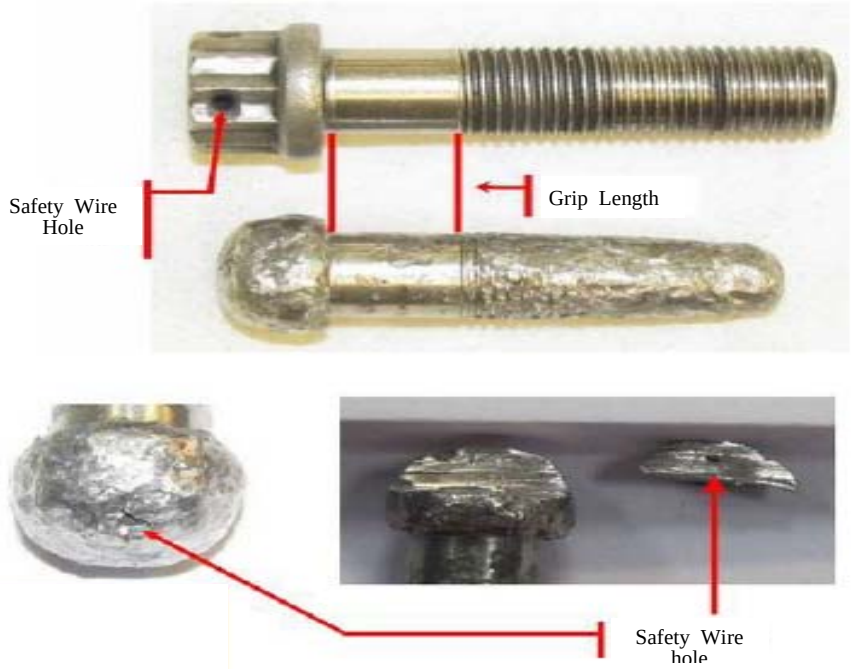
as the bolt was abraded since both the metal chip #3 and the bolt contained the same elements as aluminum, chromium, iron, and nickel.

On the other hand, metal chips #1 and 4 were determined to be the same material since the same elements as aluminum and copper were detected in both of them. Metal chips #1, 2, and 4 were determined to be a part of a cooler tube containing brass since copper was found in all of them.

2.3.4 Bolt Analysis

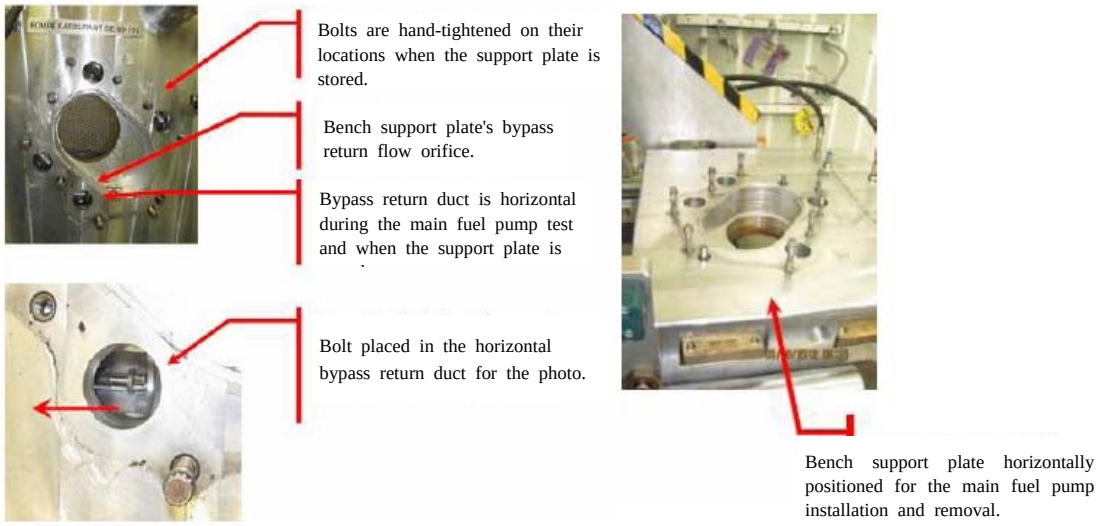
The design of the bolt was almost similar to part no. J646P21B. This bolt is used to install the main fuel pump on the bench support plate. It was not recorded in GE90 IPC, but was recorded in CF6-80C2 IPC.

As shown in [Figure 12], the bolt matched J646P21B when it comes to diameter, thread, and grip length. It also had a safety wire hole. Examination using an electron microscope revealed that the elements of both bolts coincided.



[Figure 12] Bolt Comparison

As shown in the right photo of [Figure 13], the main fuel pump bench support plate is a device on which the main fuel pump is installed and fastened. The top left photo of [Figure 13] shows the bench support plate viewed from right above. The bottom left photo of [Figure 13] is a close shot of the bypass return duct in which the bolt is placed. The duct is long enough to hide the bolt.



[Figure 13] Support Plate for the Main Fuel Pump Bench Test

The hypothesis about the engine in-flight shutdown (IFSD) caused by the bolt is as follows: the bolt was ingested into the main fuel pump strainer although the timing of the ingestion cannot be accurately identified. The strainer was not removed after the final bench test[32] to avoid damaging the O ring and a leakage, but this procedure was not requested by the OEM documentation[33].

The main fuel pump has been tested according to the Component

32) The component is installed on the test bench, energized, operated, and tested.
33) OEM: Original Equipment Manufacturing.

Maintenance Manual before its release into service. The oil analysis done after this test did not show any trace of metal chips.

During the engine operation, the bolt remained in the strainer until it damaged the strainer screen. Then, the bolt passed through the strainer and damaged the gear set. Gear tooth chips damaged the housing and the bearings and contaminated the fuel filter and fuel/oil coolers.

Low fuel flow and pressure caused by the damaged gear set led to low N1, thereby resulting in the IFSD. As fuel pressure dropped due to the IFSD, the bolt got back to the strainer.

3. Conclusions

3.1 Findings

1. Air France B777-200F aircraft, flight 6775 (ICN/CDG), registered as F-GUOB, was manufactured by the Boeing Company in the United States and delivered to Air France on February 24, 2009. The aircraft initially received the certificate of airworthiness from the French airworthiness authorities on February 27, 2009 and remained airworthy by receiving a current airworthiness review certificate in accordance with Commission Regulation.

2. The flight crew held qualification certificates proper for the applicable flight, including an air transport pilot certificate, received recurrent training, and passed their proficiency check.

3. On March 14, 2012, about 15:40, AF6775 returned to Incheon Airport since the right engine (#2 engine) N1 failed to reach N1 command approximately five minutes after takeoff, and during landing, "ENGINE FAIL R" warning message was displayed at 100 feet.

4. The pilot was supposed to turn off the A/T ARM switch according to engine limit/surge/stall procedures in the QRH, but he kept it on since the right engine's indication did not exceed its operating limits. As a result of a comparison with the FDR parameters, it is determined that he performed proper procedures.

5. On March 12 and 13, before the serious incident, the main fuel pump of the aircraft was replaced due to fuel drain leakage.

6. After air turnback, Air France maintenance technicians replaced the main fuel pump and inspected the interstage strainer installed in the main fuel pump. As a result, one bolt was found between the strainer and the housing. The bolt was embedded in the strainer screen.

7. On March 16, Air France additionally replaced the lube/servo fuel/oil cooler and IDG fuel/oil cooler due to fuel contamination during the serious incident.

8. The ARAIB analysis lab analyzed the bolt collected from the site and the metal chips in the fuel filter. The analysis revealed that the elements of the metal chips were similar to those of the bolt and the strainer gear. Thus, it is determined that fuel was contaminated due to the abrasion of the bolt in the fuel pump.

9. The inspection of the main fuel pump revealed that the gear set was damaged to the point of being unable to disassemble and that the gear housing was also severely damaged. Thus, the main fuel pump was scrapped.

10. The inspection of lube-servo fuel/oil cooler revealed that the tubes on the servo side of the unit were internally plugged with metal chips. The unit was determined to be beyond physical repair and subsequently scrapped. The internal damage to the tubes could not be determined.

11. The bolt found in the fuel pump is used to install the main fuel pump on the bench support plate. The bolt matched one used for the bench test when it comes to diameter, thread, and grip length. It also had the same safety wire hole. Examination using an electron microscope revealed that the elements of both bolts coincided.

12. The bolt for installing the main fuel pump on the test bench was ingested into the main fuel pump through the bypass return duct. The pump still with the bolt inside was installed on the aircraft. The bolt was abraded in the fuel pump due to high fuel pressure caused by the fuel pump operation, which generated metal chips. These metal chips damaged the gear set, which caused low fuel pressure, and as fuel pressure got lower, fuel was not supplied to the engine, thereby resulting in one engine in-flight shutdown.

3.2 Causes

The ARAIB determines the probable cause of the accident as follows:

「As the interstage strainer was polluted by metal chips due to foreign object ingestion, gear set was damaged, which caused low fuel pressure, and as fuel pressure got lower, fuel was not supplied to the engine, thereby resulting in one engine in-flight shutdown.」

4. Safety Recommendations

As a result of the investigation of the serious incident that occurred to AF6775 on March 14, 2012, approximately 15:40, the ARAIB issues the following recommendation.

To Air France

Develop and implement the measures to prevent foreign objects, including bolts used for a test bench, from ingesting into the fuel pump when the fuel pump is maintained at a component repair shop (AIR-F1201-1).