AI2020-2

AIRCRAFT SERIOUS INCIDENT INVESTIGATION REPORT

JETSTAR AIRWAYS PTY LTD.
V H V K J

June 25, 2020

Japan Transport Safety Board

The objective of the investigation conducted by the Japan Transport Safety Board in accordance with the Act for Establishment of the Japan Transport Safety Board (and with Annex 13 to the Convention on International Civil Aviation) is to prevent future accidents and incidents. It is not the purpose of the investigation to apportion blame or liability.

TAKEDA Nobuo
Chairman
Japan Transport Safety Board

Note:

This report is a translation of the Japanese original investigation report. The text in Japanese shall prevail in the interpretation of the report.

AIRCRAFT SERIOUS INCIDENT INVESTIGATION REPORT

CASE EQUIVALENT TO CONTINUED LOSS
OF THRUST OF ENGINES IN FLIGHT
JETSTAR AIRWAYS PTY LTD.
BOEING 787-8, VHVKJ
AT ABOUT 3,600 M ALTITUDE OVER ABOUT 90 KM
SOUTHWEST OF KANSAI INTERNATIONAL AIRPORT, JAPAN
AROUND 18:57 JST, MARCH 29, 2019

June 5, 2020

Adopted by the Japan Transport Safety Board

Chairman	TAKEDA Nobuo
Member	MIYASHITA Toru
Member	KAKISHIMA Yoshiko
Member	MARUI Yuichi
Member	MIYAZAWA Yoshikazu
Member	NAKANISHI Miwa

1. PROCESS AND PROGRESS OF THE AIRCRAFT SERIOUS INCIDENT INVESTIGATION

1.1 Summary of the Serious Incident	A Boeing 787-8, registered VHVKJ, operated by Jetstar Airways Pty Ltd. as a scheduled flight JQ15, departing Cairns Airport on March 29, 2019 at 13:11 Australian Eastern Daylight Time (AEDT: UTC＋10 hours) for flight to Kansai International Airport, had the left engine temporarily fall below idle during the descent at an altitude of about 4,900 m, followed by the right engine temporarily falling below idle as well. The aircraft landed at Kansai International Airport at 19:19 Japan Standard Time (JST: UTC＋9hours).
1.2 Outline of the Serious Incident Investigation	The occurrence covered by this report falls under the category of Article 166-4 (xvii) of the Ordinance for Enforcement of the Civil Aeronautics Act of Japan (Ordinance of Ministry of Transport No. 56, 1952), as the case equivalent to “Continued loss of thrust of engines (in the case of multiple engines, 2 or more engines) in flight” as stipulated in (vii) of the same Article, and is classified as a serious incident. The Japan Transport Safety Board designated an investigator-in-charge and two investigators on April 2, 2019 to investigate this serious incident. An accredited representative of Commonwealth of Australia, as the State of Registry and Operator of the aircraft involved in this serious accident, an accredited representative and an adviser of the United States of America, as the State of Design and Manufacture of the aircraft and engine, and an accredited representative of New Zealand as an investigating member, participated in the investigation. Comments were invited from parties relevant to the cause of this serious incident and the Relevant States.

2. FACTUAL INFORMATION

2.1 History of the Flight

According to the statements of the PIC (pilot in command) and the FO (first officer) and records of EAFR and continuous parameter logging (CPL)*1, the history of the flight was summarized as follows.

A Boeing 787-8, registered VHVKJ, operated by Jetstar Airways Pty Ltd. (hereinafter referred to as "the Operator") as a scheduled flight JQ15, departed Cairns Airport, Australia on March 29, 2019 at 13:11 AEDT with 313 persons on board, consisting of the PIC, 11 crewmembers and 301 passengers.

At 18:53 JST (unless otherwise noted, all times are indicated in JST in this report on a 24-hour clock), during the descent at an altitude of about 4,900 m (about 16,000 ft) to Kansai International Airport, the right engine instrument display became unstable with "ENG THRUST R" and "ENG CONTROL R" EICAS*2 messages appeared.

At 18:54, "ENG FUEL SPLIT VALVE R" EICAS message appeared.

At 18:57, "ENG FAIL L" EICAS message appeared and disappeared shortly thereafter at an altitude of about 3,600 m (about 12,000 ft). The PIC did not feel malfunction in the left engine parameters at this time. CPL recorded a value below idle lasting for eight seconds in the left engine.

At 18:58, "ENG FAIL R" EICAS message appeared and disappeared after a while. The PIC disengaged the right auto throttle and set the right engine thrust lever to the idle position in accordance with check list because he confirmed unstable parameters of the right engine. The right engine parameters indicated unstable until landing. CPL recorded a value below idle lasting for 81 seconds in the right engine.

At 19:08, "ENG CONTROL L" EICAS message appeared.

At 19:19, the Aircraft landed at Kansai International Airport.

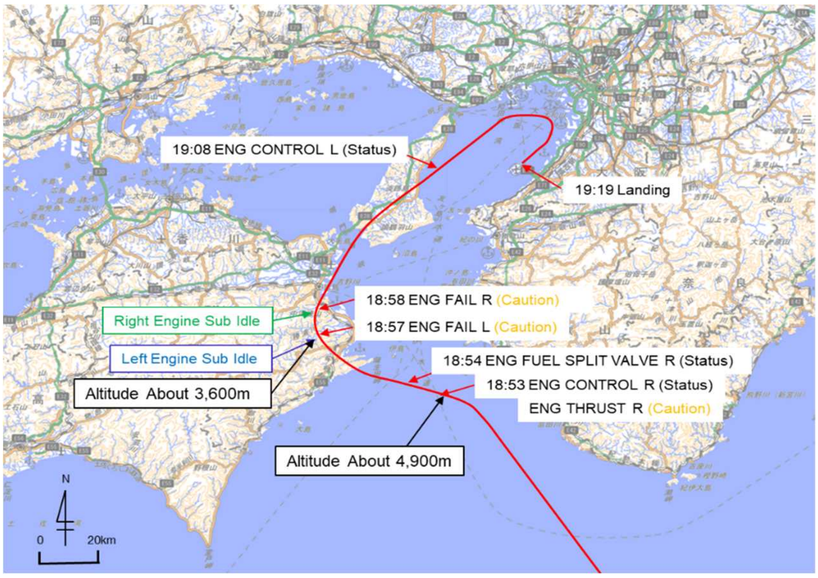

Figure 1: Estimated flight route and

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*1 "CPL (ACMF CPL: Airplane Condition Monitoring Function Continuous Parameter Logging)" denotes a recording device that monitors status of aircraft and continuously records pre-determined parameters.

*2 "EICAS" is an abbreviation of Engine Indication and Crew Alerting System, and denotes a system that indicates operational status of engines and various systems with a function to alert pilots abnormal status in visual and auditory ways in case of abnormality occurring.

This serious incident occurred at a pressure altitude of about 3,600 m over about 90 km southwest of Kansai International Airport (33° 54’ 35” N, 134° 35’ 06” E) on March 29, 2019 at around 18:57.

2.2 Injuries to Persons

None

2.3 Damage to Aircraft

None

2.4 Personnel Information

PIC Age 41

Airline transport pilot certificate (Airplane)	August 8, 2006
Type rating for Boeing 787	September 9, 2015
Class 1 aviation medical certificate	
Validity	September 9, 2019
Total flight time	12,491 hours 20 minutes
Total flight time on the type of aircraft	2,102 hours 34 minutes

2.5 Aircraft Information

(1) Aircraft

Type	Boeing 787-8
Serial number	36236
Date of manufacture	July 1, 2015
Certificate of airworthiness	DM15-00748
Category of airworthiness	the Aircraft Transport T
Total flight time	18,156 hours 48 minutes
Total flight cycles	2,644 cycles
Flight time since the last periodic check (C maintenance conducted on November 2, 2017)	6,877 hours

(2) Engines

Table 1: Engine specifications

Attached position	No. 1 (left)	No. 2 (right)
Type	General Electric GEnx-1B	
Serial number	958172	956289
Date of manufacture	September 11, 2018	July 25, 2013
Total flight time	1,602 hrs 40 min	18,556 hrs16 min
Total flight cycles	237 cycles	2,799 cycles

When the serious incident occurred, the weight and balance of the aircraft were within the allowable ranges.

2.6 Meteorological Information

Aviation routine weather report (METAR) for Kansai International Airport around the time of the serious incident was as follows:

18:30 Wind direction 240° ; Wind velocity 7 kt; CAVOK;
Temperature 13° C; Dew point 7° C;
Altimeter setting (QNH) 29.94 inHg

19:00 Wind direction 220°; Wind velocity 11 kt; CAVOK;
Temperature 12° C; Dew point 7° C;
Altimeter setting (QNH) 29.95 inHg

Weather conditions over the flight route of the Aircraft was good with no encountering icing or volcanic ash.

2.7 Additional Information

(1) Fuel Tank

Fuel tank of the Aircraft comprises left, center and right tanks. Each tank has many structural partitions called ribs that retain strength of the wing and prevent an excessive movement of fuel associated with attitude changes of the Aircraft.

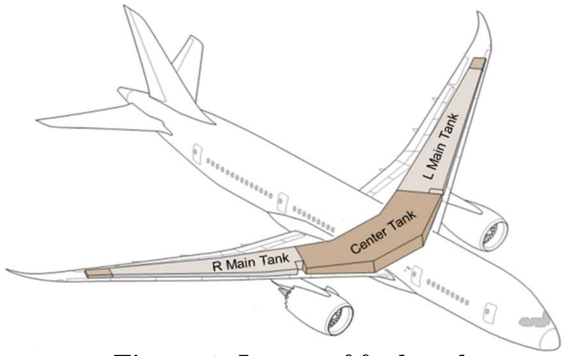

Figure 2: Image of fuel tanks

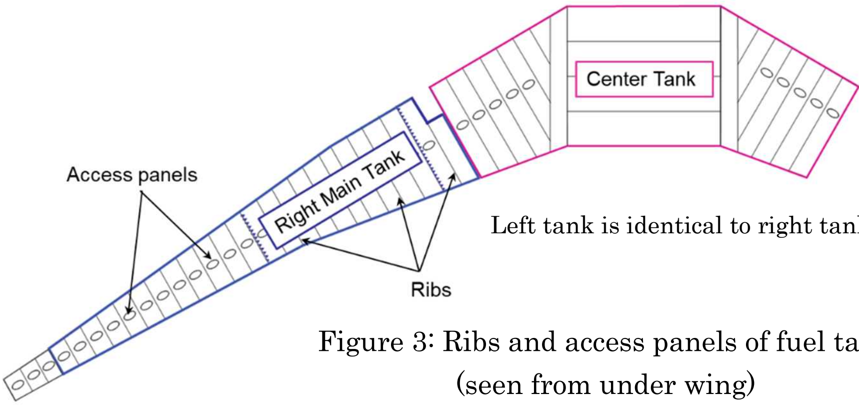

Figure 3: Ribs and access panels of fuel tank (seen from under wing)

(2) Fuel System

Fuel flows from fuel tanks through shutoff valve, and then is fed to fuel metering unit (FMU) after being pressurized in low pressure stage of the fuel pump. After passing through the VFSG and ENG Fuel/Oil heat exchangers, fuel pressure is increased by the high pressure stage of the fuel pump, and then fuel passes through the fuel filter and is fed to FMU split into for combustion and for servo. FMU has a function to shut off fuel, meters the amount of combustion fuel and supplies servo fuel to activate valves and actuators. Combustion fuel is fed to fuel splitting valve (FSV) through Flow TX after being metered in fuel metering valve (FMV). The FSV, a valve newly adopted by this engine, controls the fuel distribution to the 22 fuel nozzles based on ECU control logic. Fuel nozzles atomized fuel into combustion chamber.

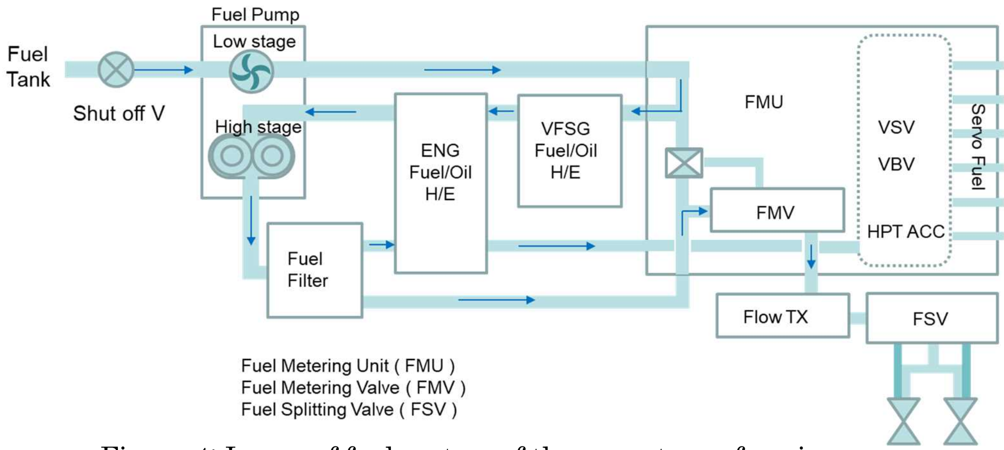

Figure 4: Image of fuel system of the same type of engine

Valves and actuators activated by servo fuel are as follows: (systems related to the serious incident only)

i) High pressure turbine active clearance control (HPT ACC)

HPT ACC minimizes a gap between blades and turbine case by spraying fan air over the circumference of high pressure turbine case, and thereby enhances operating efficiency of engines.

ii) Variable bleed valve (VBV)

VBV extracts air from compressor to optimize operating efficiency of engines.

iii) Variable stator vane (VSV)

VSV adjusts air flow inside compressor to optimize operating efficiency of engines.

(3) Sliding Spool

Sliding spools are part of servo valves which use flow to position control valves, such as FMV or FSV. Sliding spools to right and left utilizing fuel pressure by EEC controls adequate amount and fuel distribution and staging.

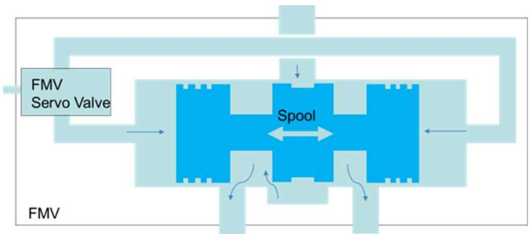

Figure 5: Image of Sliding Spool

(4) Fuel Pressure

Fuel pressure and fuel temperature varies by engine rpm (rpm N2 of engine core) because fuel pressure rises by engine-driven fuel pump.

(5) EICAS Messages

EICAS messages appeared at the occurrence of the serious incident and conditions for appearance of EICAS messages are as follows:

i) “ENG FAIL L” and “ENG FAIL R” (Caution message)[*3]

The left/right engine has run below idle speed and auto ignition has been activated to prevent flameout.

ii) “ENG THRUST R” (Caution message)

The engine is not producing commanded thrust (N1) or not responding normally to changes in thrust command.

iii) “ENG CONTROL L” and “ENG CONTROL R” (Status message)[*4]

EEC may be operating with a limited set of engine control parameters and may not be capable of controlling all aspects of the engine.

iv) “ENG FUEL SPLIT VALVE R” (Status message)

FSV spools failed open or closed or either valve position sensor has failed in both channels.

(6) Activation of Automatic Ignition

The Aircraft has a function that engine ignition is automatically turned

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*3 “Caution message” denotes a message of abnormality or failure that does not require emergency operation but should be notified to pilots immediately.

*4 “Status message” denotes a message meaning mainly malfunction information and determines departure or suspension of the flight.

on to prevent flame out when rpm falls below idle or to re-light the engine if a flameout has been detected. CPL recorded messages of "ENG FAIL L" and "ENG FAIL R" appearing along with the activation of the ignition.

(7) Oscillation of Engine RPM

Oscillation refers to the status that actual engine rpm does not stabilize repeating fluctuations up and down against required value of engine rpm calculated by EEC. CPL recorded the occurrence of rpm oscillation of both engines. The oscillation occurred during the first flight after biocide treatment conducted on March 27, and also during engines start and cruising on event flight. However, amplitude of the oscillation was so small as not to be noticed by the PIC or the FO and there was no record of EICAS message appearing either. The oscillation became remarkable enough to be recognized by the PIC and the FO during the descent to Kansai International Airport, and "ENG FAIL L" and "ENG FAIL R" EICAS messages appeared immediately

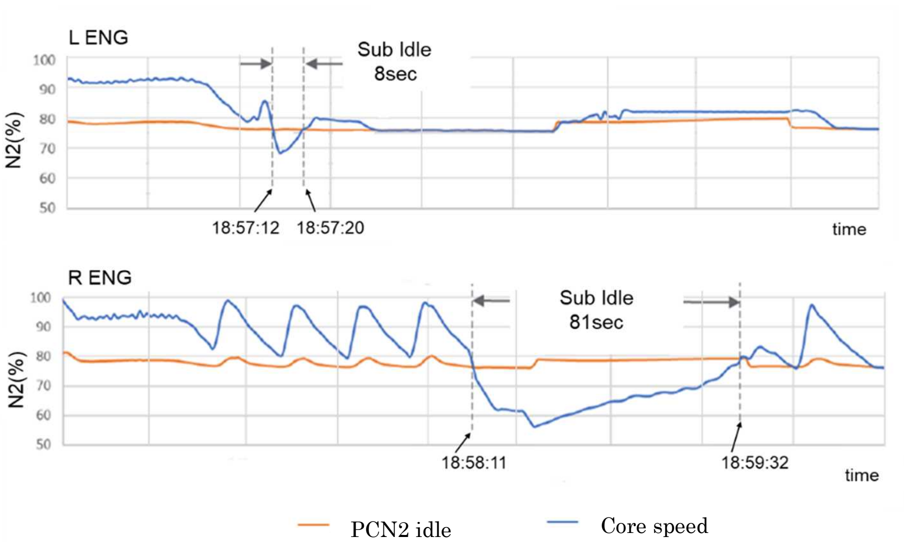


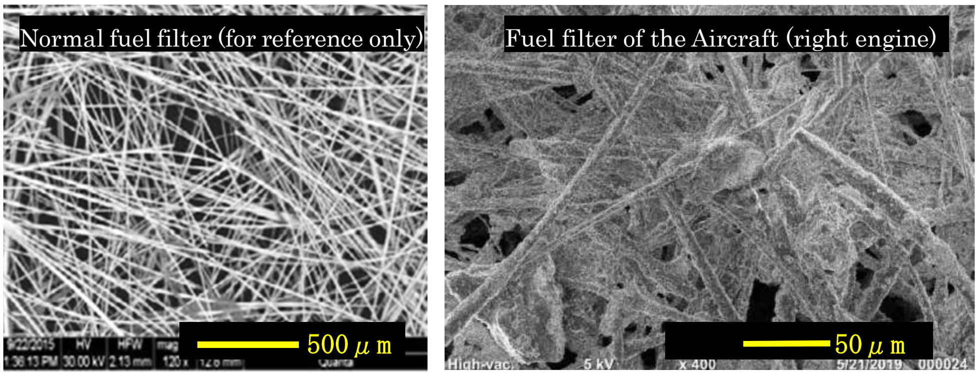
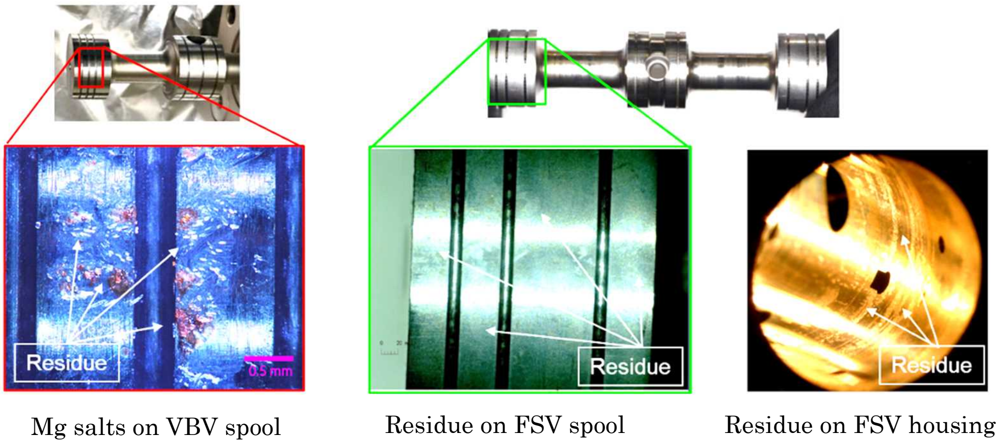
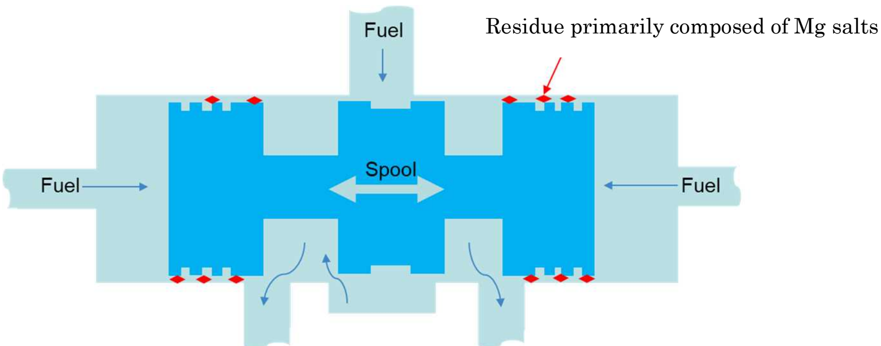
Figure 6: Engine RPM and Oscillation

thereafter. The oscillation status of engine rpm at that time was as follows. (See Figure 6)

(8) Detailed Investigation – Engine fuel components

Engine fuel system components were removed from both engines and were sent to laboratory in the United States of America for investigation to be conducted with oversight from the NTSB with following outlines of investigation report.

i) Residue was detected from fuel filter of both engines. Composition of the detected residue were similar to the ones of biocide (Kathon FP1.5).

	Note: It is possible to find some Kathon FP1.5 residue in the fuel filter after biocide treatment.  Figure 7: Fuel Filter ii) FSV spool and VBV spool of both engines did not move with Residue primarily composed of Magnesium salts being detected. Composition of the detected Residue primarily composed of Magnesium salts were similar to the ones of biocide (Kathon FP1.5). FSV spool, if it is under normal condition, moves on a test stand by the force of 0.5 lbs*5; however, the spool did not move even by applying the force of 160 lbs. Magnesium salts and residue were detected from FMV spool, HPT ACC spool and VSV spool of the left engine.  Figure 8: Residue primarily composed of Mg salts  Figure 9: Portions where the residues were detected

*5 "lb (pound)" is a unit of weight. One lb is equivalent to 0.4536 kgs.

(9) Biocide Treatment

Reviewing maintenance record of the Aircraft revealed that biocide treatment was conducted on March 27 before the serious incident. The Aircraft was ferried to Auckland International Airport, New Zealand to borrow facilities of other company to conduct biocide treatment inside all three fuel tanks (left, center and right) because the Operator did not have their own facilities. After completing the biocide treatment, the Aircraft was ferried back to Cairns Airport.

(10) Biocide Treatment Procedures

If microbial generate inside fuel tank, it is possible that it generates corrosion inside fuel tank or causes malfunction in fuel supply system. To prevent these beforehand, the Operator confirms the status of microbial growth inside fuel tank every 200 hours and conducts biocide treatment as needed although Aircraft Maintenance Manual (AMM) of the Aircraft does not stipulate biocide treatment on a regular basis.

According to the AMM, biocide treatment is conducted by connecting biocide treatment cart to a certain position of fueling hose to mix biocide with fuel for loading into fuel tank. AMM stipulates that biocide of either Kathon FP1.5 or Biobor JF is used, and the Operator used Kathon FP1.5.

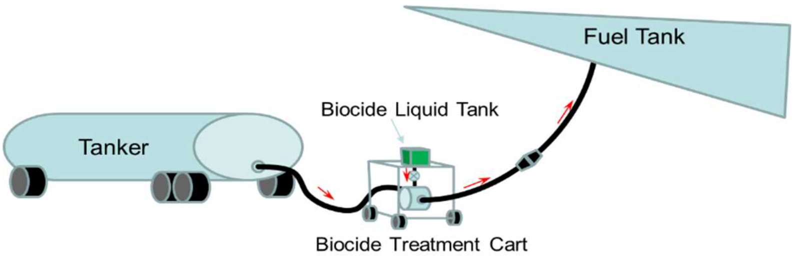


Figure 10: Image of Biocide treatment

When Kathon FP1.5 is used, biocide and fuel are loaded to make concentration ratio inside fuel tank 100 ppm (parts per million) by volume. Therefore, in the event that fuel remains in aircraft, fuel and biocide to be loaded require adjustments to obtain a higher concentration ratio for loading into aircraft so that the final concentration ratio inside the tank can be 100 ppm. After completing fuel loading, biocide treatment is completed by soaking fuel for 12 to 24 hours keeping concentration ratio inside fuel tank at 100 ppm. Biocide-treated fuel is used for normal flight operations.

(11) Biocide Treatment Method

According to the CS (Certifying Staff), they dosed biocide (Kathon FP1.5) as prescribed in AMM during biocide treatment of fuel tank of the Aircraft on March 27. The CS loaded fuel up to 25,000 kgs in concentration ratio of about 100 ppm into the center tank because remaining fuel in the center tank of the Aircraft before biocide treatment was 0 kg. Because 6,000 kgs of fuel remained in the left tank and 6,500 kgs in the right tank, respectively, the CS calculated and loaded additional fuel to make final concentration ratio of about 100 ppm by volume to 10,000kgs as shown in Figure 11. There were maintenance records related to the biocide treatment work, however, calculation of biocide concentration ratio for each tank and the dosage amount were not kept recorded.

According to the AMM, the “C uplift” should be calculated as follows.

$$C\ uplift = \frac{100\ (FUEL\ onboard + FUEL\ uplift)}{FUEL\ uplift}$$

C uplift : Concentration of fuel to be uplifted(ppm)
FUEL onboard : Quantity of untreated fuel already onboard
FUEL uplift : Quantity of fuel to be added with metered biocide

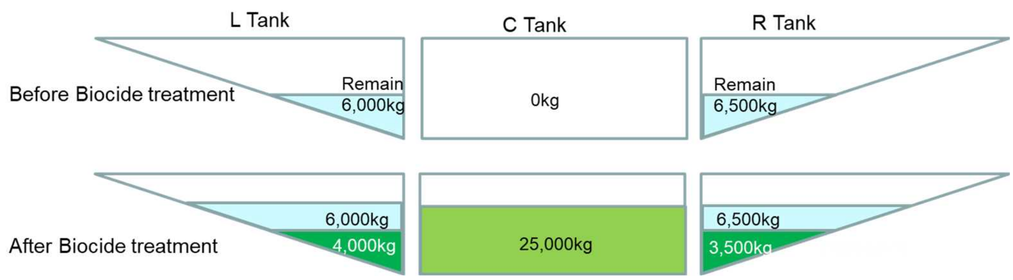


Figure 11: Image of loaded amount pre- and post-biocide treatment

(12) Composition of Biocide

Composition of two kinds of usable biocide stipulated by AMM are published by each manufacturer as follows:

i) Kathon FP1.5 (MIL-S-53021A)

- Dipropylene Glycol: 90.0%
- Water: 5.85%
- Magnesium salts: 2.65%
- 5-Chloro-2-Methyl-4-Isothiazolin-3-one: 1.15%
- 2-Methyl-4-Isothiazoliln-3-one: 0.35%

ii) Biobor JF (MIL-S-53021A)

- 2,2’-oxybis (4, 4, 6-trimethyl-1,3, 2-dioxaborinane)-2,2’-(1-methyltrimethylenedioxy) bis-(4-methyl-1, 3, 2-dioxaborinane): 95%
- Naphtha: 4.5%
- Other: 0.5%

(13) Investigation into Biocide Treatment Cart

Visual investigation, concentration ratio adjustment functional investigation and disassembling investigation of biocide treatment cart all indicated that it functioned as normal. The biocide treatment cart was maintained in accordance with inspection procedures designated by the manufacturer of the cart and record of conducting periodic inspections was kept stored.

(14) Biocide Test

Testing biocide (Kathon FP1.5) was conducted at the laboratory of the design and manufacturer of the engines with the result described below.

	Testing biocide was conducted by changing concentration ratio, temperature and pressure to simulate actual flight condition. Device for experiment was also activated by using actual spools to simulate fuel system to observe precipitation. Magnesium salts contained in Kathon FP 1.5 are insoluble in fuel. Magnesium salt will dissolve into water if a water phase is present in the fuel. Magnesium salts can precipitate or accumulate in spools through the engine fuel system. It was confirmed that amount of precipitated Magnesium salts increased commensurate with the rise in biocide concentration ratio. (15) Investigation inside Fuel Tanks of Aircraft Fuel remained in all tanks was drained after the serious incident, and multiple locations inside each tank were wiped out with cotton swabs for composition investigation, but there was no finding residue of microbial or biocide in all the tanks and sampled fuel. (16) Similar Cases Investigation into similar cases revealed that there were six cases reported in which both engines could not start in twin engine aircraft, and one case each in which all engines could not start in four-engine aircraft and engine thrust could not be adjusted. Any of these cases were presumed to have been caused by concentration ratio of biocide (Kathon FP1.5) that was set at higher values (about 1,000 ppm) than specified ones during biocide treatments. The design and manufacturer of the Aircraft, based on these cases, provided pertinent information with operators referencing the concentration ratio prescribed in AMM. (17) Gathering Information from Operators of Same Type of Engine After the serious incident, the design and manufacturer of the Aircraft gathered information on conducting biocide treatment from operators of the same type of the engine. Summary of biocide treatment history of over 65 GEnx-powered aircraft during the last five years revealed that any malfunction was not reported.

3. ANALYSIS

3.1 Involvement of Weather	None
3.2 Involvement of Pilot	None
3.3 Involvement of Aircraft	Yes
3.4 Analysis of Findings	(1) From statements of the PIC and the FO and the records of EAFR and CPL, it is highly probable that rpm of each engine, at separate times, temporarily fell below idle during the descent to Kansai International Airport. (2) From the results of detailed investigation of engine fuel components, accumulation of Residue primarily composed of magnesium salts was observed in multiple locations (fuel filter, FMV spool, FSV spool, VBV spool and HPT ACC spool). It is probable that biocide treatment inside fuel tanks conducted

	two days before the serious incident was involved in the accumulation of Residue primarily composed of magnesium salts because the composition of the residue were similar to the Kathon FP1.5. (3) It is highly probable that Residue primarily composed of magnesium salts accumulated in FMV spool and FSV spool, which meter engine combustion fuel, restricted movement of spools, caused inadequate fuel metering, thereby led to engine rpm oscillation that occurred from the first flight after conducting biocide treatment. (4) It is highly probable from CPL record that engine rpm oscillations was caused by the condition that FMV spool and FSV spool had restricted freedom of movement when fuel pressure was low, and moved more freely when fuel pressure was high. Besides, it is highly probable that engine rpm temporarily fell below idle due to fuel flow that was significantly reduced by movement of FSV spool when engine rpm was reduced to near idle during the descent for landing. It is highly probable that EICAS messages of "ENG FAIL L" and "ENG FAIL R" appeared because the engines temporarily fell below idle. (5) From the results of the interview with the CS who was in charge of biocide treatment work, it is probably that the CS calculated according to the AMM so that the recommended final concentration ratio in the tanks would be about 100 ppm, and additionally loaded the treated fuel as described in 2.7 (11). According to the AMM calculation formula, the concentration ratio of the additional biocide treated fuel is calculated to be about 250 ppm in the left tank and about 285 ppm in the right tank. However, there was no record of the calculation of the concentration ratio of the biocide and the dosage amount. It is desirable to keep these records because they are considered to be important for traceability of maintenance work. (6)From the result of investigation on the inside of fuel tanks after the serious incident, it is somewhat likely that the fuel with higher concentration ration of biocide, which was supplied to the engines did not mix evenly inside the fuel tanks because no residue of microbial or biocide was found inside the fuel tanks and in the sampled fuel. (7) As for the reason why the fuel did not mix evenly inside the fuel tanks, it is somewhat likely that it is affected by the fuel temperature and density of as well as inner structure of fuel tanks; however, it could not be determined how much the fuel was not mixed. (8) From the biocide test result, it is probable that Magnesium salts contained in biocide did not dissolve in fuel, but dissolved in water contained in fuel and were accumulated in spools as crystals through the engine fuel system.

4. PROBABLE CAUSES

In this serious incident, it is highly probable that, when the Aircraft was descending for landing, there occurred oscillation in rpm of each engine causing both engines to temporarily fall below idle at separate times because Residue primarily composed of magnesium salts accumulated in spools impeded movement of spools that involved in fuel metering of both engines.

As for the higher accumulation of Residue primarily composed magnesium salts in spools, it is somewhat likely that the fuel with a higher concentration ratio of biocide, which was loaded in the biocide treatment two days before the serious incident, did not mixed evenly with the remaining fuel in wing tanks, and was fed to the engines.

5. SAFETY ACTIONS

(1) The Operator suspended biocide treatment using Kathon FP1.5 inside fuel tanks of the same type of aircraft. The Operator is reviewing maintenance procedures that occur infrequently, to identify task- specific training opportunities for maintenance personnel based on AMM.

(2) The design and manufacturer of the engine issued service bulletin (SB) for aircraft equipped with GEnx engine to notify operators to suspend biocide treatment using Kathon FP1.5. (SB 73–0086 R00 ENGINE FUEL AND CONTROL – GENERAL (73-00-00) – SUSPENSION OF THE USE OF KATHON FP 1.5 BIOCIDE TREATMENT ISSUED SEP/30/2019)

(3) The design and manufacturer of the aircraft deleted biocide treatment procedures using Kathon FP1.5 from the AMM of the same type of aircraft equipped with GEnx engine following SB issued by the design and manufacturer of the engine. The design and manufacturer of the aircraft also updated the AMM for all models of aircraft to explicitly describe the maximum allowable biocide concentration ratio and to record calculation of biocide amount and the amount used.

(4) After receiving multiple reports of similar cases using Kathon FP1.5, the Federal Aviation Administration (FAA) issued SPECIAL AIRWORTHINESS INFORMATION BULLETIN (SAIB NE-20-04 Date: March 25, 2020 Engine Fuel – Jet Fuel Biocide Additive) and the European Union Aviation Safety Agency (EASA) issued Safety Information Bulletin (SIB No.: 2020-06 Issued: 20 March 2020 Use of DuPont Kathon FP 1.5 Biocide) to notify operators, repair stations, aircraft and engine manufacturers regarding the use of Kathon FP1.5. In addition, the Civil Aviation Safety Authority (CASA) issued AIRWORTHINESS BULLETIN (AWB 28-018 Issue 1 – 26 March 2020 Suspending Use of Kathon Biocide for Treating Micro-biological Growth in Aviation Fuel) to strongly recommend to suspend the use of Kathon FP1.5 for biocide treatment.