



Fuel monitoring on A320 Family aircraft

Since the first A320 entry into service, very few events have involved undetected fuel quantity issues. Yet, coming across a situation where engines shut down by lack of fuel is a situation no one wants to experience.

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If fuel systems have proven their reliability, in case of failure, the ultimate safety barrier to avoid finding oneself in a fuel critical situation is fuel monitoring by the crew. Let's go back to some fundamental questions around fuel monitoring on A320 Family aircraft. How to determine the fuel quantity available in the tanks? What are the various sources of information and how redundant are they? Why is it key to perform regular fuel checks?

RARE BUT STRIKING EVENTS

In more than 25 years of Airbus A320 Family aircraft operation, there have been not more than a handful of events involving undetected fuel quantity issues.

The reasons for these fuel quantity issues vary from one event to another. Early detection and management of the issue remains key to successfully deal with such events.

Event 1

During cruise of an A320 Family aircraft, the crew observed 3 occurrences of the ECAM warning L TK PUMP 1 + 2 LO PR. In line with this warning, they noticed a more rapid fuel level decrease in the left fuel tank compared to the right one. Following the applicable FCOM procedure, they opened the fuel cross feed valve, only to close it soon after as fuel quantity was abnormally decreasing. Minutes later, engine 1 shut down by itself and the ECAM warning ENG 1 FAIL triggered.

The crew managed to land the aircraft uneventfully with engine 2 still running,

and passengers disembarked safely. The remaining fuel quantity upon landing turned out to be 840 kg in the right fuel tank, and no fuel in the left tank.

Investigation into this event highlighted that maintenance was done on the fuel tanks prior to the event flight, and both engines 1 and 2 fuel pump filters had been replaced. After the event flight, engine 1 HP fuel pump filter cover was found not properly fitted, with 4 threaded inserts out of 6 being reported unserviceable, thus allowing the cover to partially open. It was estimated that approximately 4 to 5 tons of fuel had leaked.

Event 2

In another event, the Fuel Quantity Indication (FQI) system had been showing discrepancies for a period of time. Given the intermittent nature of the fault, entries in the aircraft logbook were investigated but without findings by maintenance despite carrying out precautionary maintenance. On two occasions, different crews failed to identify or properly record the FOB discrepancy during pre-departure or post-flight fuel checks.

For the event flight, the aircraft departed with an indicated FOB of approximately 5000kg (fuel at arrival from previous leg was approx. 3800kg and fuel uplift was 1200kg). The flight crew performed the initial fuel checks with reference to the fuel logs of the preceding flight. The calculated values remained consistent.

In flight, transient fuel quantity fluctuations were experienced and eventually the ECAM alert FUEL L (R) WING TK LO LVL triggered. It was pro-

cessed as per SOP by the crew who checked the SD page as being nominal. The alert was thus considered spurious. The flight continued with repeated fuel checks at short intervals; however during the approach, engine 1 flamed out. Landing was performed on engine 2 safely. After the flight, the left wing tank was

confirmed empty with the FQI over reading by 1 ton.

The analysis of the event indicated that preceding fuel log entries did not allow the crew to identify a significant discrepancy of about 800 kg prior to departure.

Event 3

On the third flight of the day on an A320 Family aircraft, while the aircraft was approaching its destination, a LO LVL alert triggered on one side. The crew considered it spurious, as likely resulting from fuel movement in the tank. Shortly after this first alert, a new LO LVL alert triggered on the other side. The crew continued the flight and eventually landed uneventfully. The remaining fuel quantity upon landing turned out to be approximately 900 kg.

During the first flight of the day, the flight crew calculated a ~500 kg discrepancy at arrival. Nothing was mentioned in relation to fuel in the log book.

During the second flight of the day, the discrepancy calculated by the crew at arrival was almost 3000 kg. The First Officer noticed that it was not what he had expected but considered that they had benefited from a number of favorable factors such as a direct ATC routing, and they eventually had arrived 20 to 25 minutes earlier than scheduled. In addition, they sometimes ferry fuel according to the company policy. As a consequence, nothing unusual was mentioned in the log book.

Before the third flight - which was the event flight - the refueler only added little fuel since there was still a fuel over read. Yet, the flight crew



departed with a significantly over-estimated fuel quantity that ultimately led to the unanticipated LO LVL alerts on both sides. According to the investigation, the issue/over-

read was due to an intermittent FQI Computer (FQIC) failure. The maintenance record of this FQIC highlighted numerous returns to the shop in the months preceding the event.

HOW MUCH FUEL IS AVAILABLE ONBOARD?

Considering the consequences of running out of fuel in flight, knowing how much fuel is available on board during the flight is clearly essential to safety. What information can be used to determine the amount of fuel on board? How is this information established? Do the various pieces of

information relate to one another? Are they independent? Let's explore the various types of onboard fuel information that are available to the flight crew. Where does this information originate and how are fuel levels established on Airbus A320 Family aircraft?

FQI or Fuel Quantity Indication: a source based on measures performed inside fuel tanks

The FQI system calculates the fuel quantity based on values taken from probes in the tanks. The probes measure the level of the fuel in the tank, as a consequence of changing capacitance due to the amount the probe is immersed. This allows the determination of the fuel volume in the tank.

Yet the information that is needed by pilots is the quantity of fuel on board expressed as a weight. The translation of fuel volume into fuel weight is performed by the FQIC using the fuel density measured by specific devices in each wing tank **(fig.1)**.

INFORMATION

The low level sensing does not appear on the System Description page. Therefore, for fuel indication, do not rely on SD page only.

Fuel Flow Meters: a source based on engines consumption

Each engine is equipped with Fuel Flow Meters that measure the quantity of fuel consumed by the engine. This infor-

mation is integrated by the FADEC and provides pilots with information on the fuel used.

Low level sensors: an additional independent source based on dedicated sensors in the wing tank

In addition to the sensors and probes feeding the FQI system, each wing tank is equipped with

three independent dedicated low level sensors. These sensors are located in such a way that they

(fig.1)

FUEL System page on Lower ECAM Display Unit





(fig.2)

Low level alert display on ECAM

become dry when the remaining fuel in the tank is approximately 750 kg. If two sensors in the same tank remain dry for more than 30 seconds, a low level alert triggers in the cockpit (fig.2).

The low level sensors are fully independent from the Fuel Quantity Indication, and are different in that they:

- Do not provide pilots with a continuous indication of the fuel quantity in the wing tanks, but only the signal that the fuel level has reached below 750 kg (threshold crossed).
- The information provided to pilots in the form of the low level alert results from a physical measure (sensors dry or wet) rather than from a calculation.

? DID YOU KNOW

The A320 Family aircraft low level indication is based on remaining fuel quantity in the tank being sufficient to meet the requirement of 30 minutes at 1500 ft (corresponding to approximately 1 200 kg). Should the low level alert trigger on both fuel tanks, the total remaining fuel is: 750kg + 750kg = 1 500 kg.

i INFORMATION

“ The low level sensors are fully independent from the Fuel Quantity Indication. ”

The presence of water in the fuel tanks can lead to erroneous (over reading) fuel indications. The parameters used by the fuel system (density and capacitance) are highly affected by the presence of water. Flight deck effects of a buildup of water in the fuel tanks include fuel gauging fluctuations and over reads.

Consequently, among the maintenance tasks that are to be performed if pilots detect an abnormal fuel indication during a fuel check is fuel tank draining (fig.3). This can also help to prevent microbiological contamination, which is often another cause of fuel gauging fluctuations.

R	TASK NUMBER	ZONE	DESCRIPTION	ST/SIT/	SOURCE	REFERENCE	Men M.H.	APPLICABILITY
R	281100-01-2	190 100 100	TANKS DRAIN WATER CONTENT NOTE: DEPENDING ON OPERATING ENVIRONMENT AND OPERATORS EXPERIENCE, A LESS FREQUENT OR MORE FREQUENT INITIAL INTERVAL MAY BE USED. ACCESS: 195BR 196BR	AF SVC 36 HR NOTE	MRB 9	AMT 123328-281-001	1 0 10 1 0 10 1 0 10	ALL
							A 0 04	

(fig.3)

Maintenance Planning Document – ATA 28 Fuel – Task 281100-01-2 – Drain water content in tanks

FUEL CHECKS

An unnecessary burden or essential safety net?

Ensuring an accurate awareness of the quantity of fuel on board requires use of several sources of data. Certainly the FQI is the primary source of fuel indication, but the other key sources such as the Fuel Used, the fuel uplifted at the latest refuel, the crosscheck between what is expected to be uplifted and what is uplifted, information from the refue-

ler and fuel consumption figures during flight, are all important. But to ensure the information remains accurate, the safety barrier common to all cases is fuel monitoring by the crew.

Although fuel checks with the manual calculations they involve can sometimes be perceived as a tedious task,

they form in reality an integral part of the measures taken to ensure safe operations. They were designed and meant for detecting as early as possible any fuel quantity issue, ensuring timely and accurate maintenance intervention, and allowing appropri-

ate measures to secure the safety of the flight. They are applicable to all Airbus Families aircraft from the first A300B to the latest A350, and remain an essential part of airmanship when piloting the A320 Family aircraft.

“ The fuel available onboard can be determined based on two independent sources of information... even three in case of low level. ”

What is to be checked and when?

The maximum efficiency of fuel checks relies on the flight crew performing a number of checks regu-

larly and at different times to either confirm anticipations, or detect any discrepancy.

Before start

The first fuel check to be performed is before start to consolidate the information about the total amount of fuel

available for the flight. This check consists in making sure that:

$$\text{Initial Fuel On Board (FOB) + Fuel Uplifted} \\ = \text{Fuel On Board (FOB)} \pm \Delta$$

Where

FOB is the fuel quantity derived from the FQI system

Fuel Uplifted is the amount of fuel indicated by the refueler as having been added during refueling. This may require converting volume into weight,

based on the uplifted fuel density.

Δ is an acceptable tolerance (see *Why do we need to consider a certain tolerance on fuel onboard values?* insert).

During the flight

During the flight, fuel checks mainly aim at detecting any abnormal consumption, be it due to a leak or unanticipated drag (e.g. spoiler or landing gear, slats or flaps not fully retracted) or any other reason.

Indeed, such situation would make

the FMS fuel predictions too optimistic and potentially lead to fuel exhaustion in flight.

To ensure that there is no undetected fuel leak, the following calculation should be performed at each way point or every 30 minutes:

$$\text{Fuel On Board (FOB) + Fuel Used} \\ = \text{Initial Fuel On Board (FOB)} \pm \Delta$$

Where

Fuel Used is derived from the fuel flow meters

In addition, the remaining FOB and Fuel Used values must also be consistent with the values given by the computed flight plan at each waypoint.

“ All fuel checks are equally important in the detection and safe management of any fuel quantity issue. ”

Post flight

At the end of the flight, when the aircraft has reached its parking stand, a final fuel check is to be performed to check the consistency between the information provided by the var-

ious sources and thus detect any abnormal discrepancy that would call for maintenance actions. The post flight fuel check consists of making sure that:

$$\text{Fuel On Board (FOB) + Fuel Used} \\ = \text{Initial Fuel On Board (FOB)} \pm \Delta$$



NOTE

WHAT IF A FUEL CHECK IS MISSED?

Depending on the underlying reason for a fuel quantity issue, missing a fuel check may make it very difficult to detect. In the second event described, the failure of the Fuel Quantity Indication Computer did not lead to a systematic wrong indication but rather to quantity fluctuations. The fuel quantity indicated by the FQI system before the first flight of the day was correct. In such cases, skipping a fuel check may be a missed opportunity to detect a failure that may not be detectable later on, at the time of the following check. More generally, whatever the origin of a fuel quantity issue, detecting it as early as possible allows for managing it and making sure appropriate decisions can be made in time to best manage the rest of the flight as safely and efficiently as possible.

WHY DO WE NEED TO CONSIDER A CERTAIN TOLERANCE ON FUEL ON BOARD VALUES?

Due to the nature of the fuel system, it is essential that the system tolerance be taken into consideration when performing fuel quantity calculations. The overall FQI system accuracy is designed to take into consideration several factors such as: attitude effects, wing deformation, systems tolerances, manufacturing tolerances, component tolerances, environmental effects, fuel characteristics.

These individual tolerances lead to an overall tolerance on the global system resulting from the worst case (maximum tolerance) on each individual element.

The maximum tolerance is defined for the aircraft to guarantee an acceptable level of integrity of the measure and the associated fuel quantity information. When a fuel check is performed, any fuel discrepancy calculated by the crew and exceeding this value may then be considered abnormal.

For an A320 Family aircraft, the instrumental tolerance on the ground is calculated as follows:

$$\pm (1\% \text{ of current FOB} + 1\% \text{ max possible FOB for this aircraft})$$

As an illustration, for an A320 aircraft, if there are 5 tons left in the aircraft, the maximum normal tolerance value is:

$$\pm (5000\text{kg (current FOB)} * 1\% + 20000\text{kg (max FOB)} * 1\%) = \pm 250\text{kg}$$

Note: The FQI system is designed in such a way that the lower the fuel quantity in the tank, the more accurate the fuel indication.

The FQI system is calibrated on ground during manufacturing and its accuracy (as per the formula above) will remain the same throughout the operational life of the aircraft.

TO FURTHER ENHANCE SAFETY...

Following the investigation of real events involving fuel monitoring issues, Airbus identified and implemented enhancements in several areas:

- Further refinement of the description of the Fuel Quantity Indicating and level sensing systems in the FCOM documentation. During the interactions with the airlines involved, it turned out that the independence of the two fuel measures coming from respectively the FQI system and the low level alert was not clear to all crews.

- Definition of empirical criteria on A320 Family aircraft to consider a fuel discrepancy “abnormal” or “unusual” when performing the before start fuel check. These thresholds will be expressed in

kg or lbs and will vary depending on the fuel on board and fuel uplifted. They will lead to a generic maintenance task in the TSM (Trouble Shooting Manual).

- Service Bulletin A320-28-1214 for A318/A319/A320 and Service Bulletin A320-28-1202 for A321 aircraft introduce a new fuel leak detection function, which eases and improves the detection of a fuel leak. This new function is meant to prevent situations where a loss of fuel would remain undetected by the crew.

- A new FCOM evolution will be available soon, that will describe the triggering conditions of the low level alert in the procedure, and to show that the alert is independent of the displayed fuel. ■



DID YOU KNOW

A “GOLDEN RULE” IN THE TROUBLE SHOOTING MANUAL (TSM)

Until recently, there was no generic entry into the TSM in case of abnormal fuel quantity. It is therefore worth reminding everyone of a key sentence in the introduction of the TSM that encourages airlines to manage cases where there may be a doubt as to the aircraft airworthiness:

“If you cannot find a fault symptom and/or a fault isolation procedure necessary to ensure the continued airworthiness of the aircraft, or if you think that the information given is not complete, contact Airbus”.

An engine failing in flight, because of fuel starvation, is a situation all pilots would like to avoid. In order to do so, and to ensure the continuing accuracy of the FQI, performing thorough fuel checks before start, throughout the flight and after arrival at the parking stand is essential.

Should any discrepancy appear, effectively tackling the underlying issue, be it intermittent or permanent, is the only way to prevent further fuel quantity indication and possible resulting safety issues. This relies on good cooperation between flight crews, maintenance and the manufacturer.

Should the LO LVL alert trigger, it is to be trusted! It is the independent voice from the tanks themselves warning you ...

Safety first

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