

AAIB Bulletin S1/2020

SPECIAL

SERIOUS INCIDENT

Aircraft Type and Registration:	Airbus A321-211, G-POWN	
No & Type of Engines:	2 CFM CFM56-5B3/3 turbofan engines	
Year of Manufacture:	2009 (Serial no: 3830)	
Date & Time (UTC):	26 February 2020 at 0009 hrs	
Location:	London Gatwick Airport	
Type of Flight:	Commercial Air Transport (Non-Revenue)	
Persons on Board:	Crew - 7	Passengers - None
Injuries:	Crew - None	Passengers - N/A
Nature of Damage:	Fuel system contamination	
Commander's Licence:	Airline Transport Pilot's Licence	
Commander's Age:	28 years	
Commander's Flying Experience:	5,059 hours (of which 4,855 were on type) Last 90 days - 87 hours Last 28 days - 17 hours	
Information Source:	AAIB Field Investigation	

Introduction

At 0009 hrs on 26 February 2020, G-POWN took off from London Gatwick Airport for a flight to London Stansted Airport. At approximately 500 ft agl in the climb, there was a loud noise and flames were seen coming from the tailpipe of the No 1 engine as it surged. The crew made a MAYDAY call and turned right to return to the airport. Two minutes later, parameters relating to the No 2 engine began to fluctuate and the crew received an indication that the engine had stalled. The aircraft landed at 0020 hrs.

This Special Bulletin contains facts which have been determined up to the time of issue. It is published to inform the aviation industry and the public of the general circumstances of accidents and serious incidents and should be regarded as tentative and subject to alteration or correction if additional evidence becomes available.

The AAIB classified the event as a serious incident and began an investigation on 26 February 2020 in accordance with established international arrangements. The AAIB is being assisted by Accredited Representatives appointed by the Bureau d'Enquêtes et d'Analyses pour la Sécurité de l'Aviation Civile in France, the National Transportation Safety Board in the USA, and the Aircraft Accident and Incident Investigation Board in Cyprus. The Accredited Representatives are supported by Technical Advisors from the aircraft and engine manufacturers.

This Special Bulletin contains preliminary information about the investigation and is intended to highlight the importance of using correct procedures when dosing fuel with biocide to combat microbial contamination.

History of the flight

In the 24 hours preceding this serious incident, G-POWN suffered engine abnormalities across four flights and with two sets of flight crew. The serious incident occurred on the final flight.

The crew who experienced the serious incident (crew A) operated the first of the four flights, positioning¹ G-POWN from London Stansted Airport (Stansted) to London Gatwick Airport (Gatwick). At around 0520 hrs, they started the No 2 engine normally, but experienced problems starting the No 1². Commander A reported that an engineer, who was assisting with the engine starts via an external headset, advised them to attempt another start on the No 1 engine, which was successful. There were no further engine abnormalities during that flight.

At Gatwick, crew A rested at a hotel while a different crew (crew B) operated G-POWN on a return charter trip to Krakow International Airport (Krakow), Poland. Crew A were scheduled to re-position the aircraft back to Stansted later that night, along with five members of cabin crew.

The engines functioned normally on the outbound flight to Krakow. However, the No 1 engine required more than one attempt to start successfully for the return flight, at around 2000 hrs. Commander B stated that he notified the operator of the starting problem via a datalink³ message from the aircraft after departure from Krakow.

Later in the flight, the Electronic Centralised Aircraft Monitoring (ECAM) system displayed the message ENG 2 STALL momentarily on two occasions. Crew B felt vibration in the airframe; on the second occasion the message occurred during the descent when the N_1 ⁴ was around 66%. The engine control indications appeared normal but because crew B perceived the vibration to be less at lower thrust settings, they attempted to maintain the N_1 below 50%.

Footnote

¹ Positioning flight – a flight without passengers.

² The No 1 and No 2 engines are on the left and right respectively (looking forwards). The No 2 engine is often started first.

³ Datalink – A system of text messaging between aircraft and ground stations.

⁴ N_1 – the engine's fan speed, shown on a gauge in the cockpit.

On arrival at Gatwick, at around 2230 hrs, commander B phoned the operator's Technical Control department to report the No 2 engine stall event. An EASA Part-66 B1 licensed engineer then attended the aircraft⁵, and commander B recorded the defect in G-POWN's technical log.

When crew A returned to the aircraft, commander A liaised with crew B, the Gatwick engineer, and Technical Control regarding the engine abnormalities. The Gatwick engineer had completed a troubleshooting procedure during which no fault had been apparent. He signed off the engine stall defect and the Certificate of Release to Service in G-POWN's technical log. Commander A agreed with Technical Control that he would accelerate the engines to 50% N_1 for longer than usual before taking off⁶ to check the engine control indications.

At 2349 hrs, crew A started the No 2 engine normally but experienced difficulties starting the No 1, and commander A telephoned Technical Control. They suggested that the No 1 engine's abnormalities were associated with starting only and to attempt another start – which was successful.

Crew A reported accelerating the engines to 50% N_1 against the footbrakes on Runway 26L (Rwy 26L). The engine control indications appeared normal, so they commenced the takeoff at 0009 hrs (the flight is shown in Figure 1).

At around 500 ft agl, the No 1 engine began banging and surging. Commander A recalled that the engine's control indications were fluctuating, and the aircraft was "yawing... and fishtailing... all over the place". There was no accompanying ECAM message. Data recorded on the flight data recorder subsequently showed that the No 1 engine N_1 reduced below 40% for a period of approximately 25 seconds despite the thrust levers remaining in the FLEX/MCT⁷ detent.

A number of cabin crew saw flames coming from the No 1 engine's tailpipe and attempted to contact crew A using the interphone.

Commander A transmitted a MAYDAY call, requesting a return to Rwy 26L and issued an alert call⁸ to the cabin crew. He disengaged the autopilot and turned right, downwind. He moved the No 1 engine's thrust lever to idle. At one stage after doing so, he recalled seeing the No 2 engine's control indications begin to fluctuate.

Just after commencing descent from around 3,600 ft agl, the ECAM message ENG 2 STALL was displayed three times in quick succession. This prompted commander A to move the No 1 engine's thrust lever forward out of idle. He commented that both engines appeared more stable when the thrust was reduced while descending, and he aimed to maintain each engine's N_1 at around 49%.

Footnote

⁵ This engineer is referred to as the Gatwick engineer throughout the report.

⁶ A procedure used to check engine control indications before applying takeoff thrust.

⁷ The FLEX/MCT detent is a gate into which the thrust levers were moved for takeoff.

⁸ A standard procedure to alert the cabin crew in an emergency.

Co-pilot A prepared the aircraft's flight management guidance system for a return to Rwy 26L, and commander A positioned the aircraft on a 9 nm final approach. He opted to fly slightly above the glidepath in order to minimise the thrust required by the engines, and so he could glide the aircraft to the runway if the engine problems worsened. The aircraft landed at 0020 hrs, with the reverse thrust appearing to function normally.

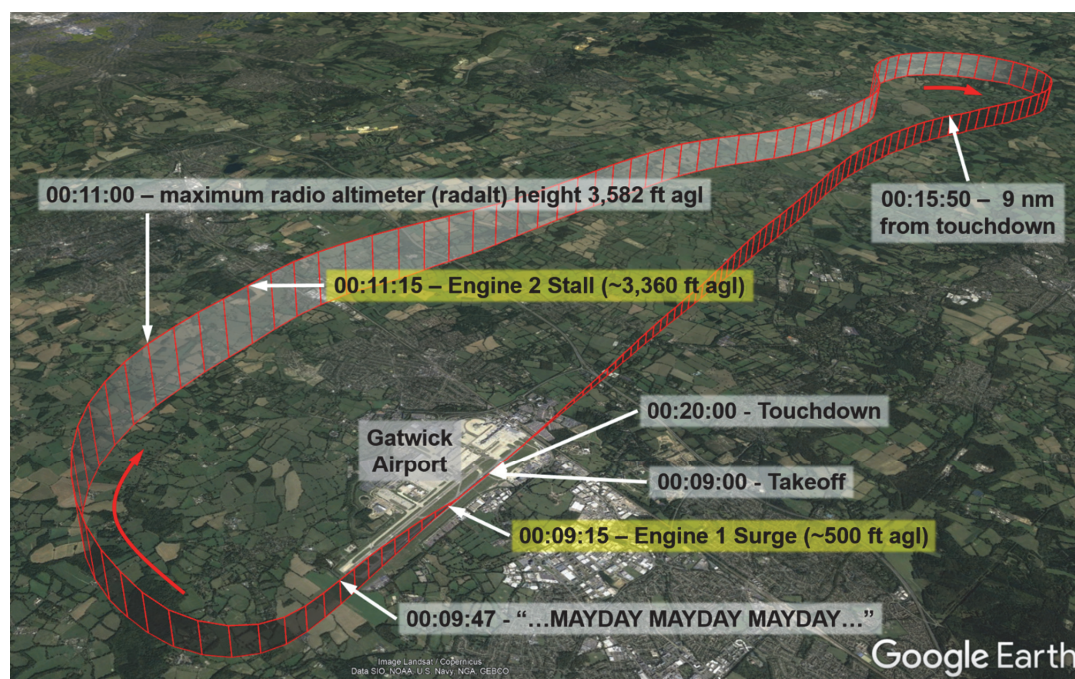


Figure 1

Radar track of G-POWN with timing of significant events highlighted

Maintenance actions

Scheduled maintenance

G-POWN was scheduled to enter a period of extensive maintenance in late January 2020 with an EASA Part-145 Approved Maintenance Organisation (AMO). As a pre-requisite, on 23 November 2019 the operator took fuel samples from the aircraft tanks to be tested for microbial contamination, in accordance with the Aircraft Maintenance Manual (AMM) Task 12-32-28-281-003-A, *Sample Fuel for Microbiological Contamination Analysis*. The samples were sent to a laboratory and it was determined that there was moderate contamination⁹. The AMM task states that a second test is required no more than 10 days

Footnote

⁹ Definition of contamination levels:

Contamination	Water Sample	Fuel Sample
	Colony Forming Units / ml	
Negligible	<1000	<4000
Moderate	>1000 <10,000	>4000 <20,000
Heavy	>10,000	>20,000

after the first test and, should this show positive, then biocidal treatment should be applied to the fuel tanks within a further 10 days. A work card for the treatment of the tanks was raised by the operator and sent to the AMO on 8 January 2020 for inclusion in the scheduled maintenance. No further microbiological testing was performed.

The aircraft entered the AMO's hangar on 23 January 2020 and the maintenance started. For most of this time, all the fuel tank access panels were open to allow work to be carried out inside the fuel tanks until 19 February 2020 when the aircraft was moved outside. Once outside, the fuel tanks were leak-checked and treated for moderate microbial contamination.

The operator's work card called for biocidal shock treatment for moderate contamination with fuel mixed with Kathon FP1.5 biocide (Kathon) in accordance with AMM Task 28-11-00-600-008-A01, *Biocidal Shock Treatment for Moderate Contamination - With Fuel Mixed with Kathon Biocide*. The biocidal treatment was not designated a 'Critical'¹⁰ maintenance task by the AMO. The task states that fuel should be mixed with Kathon biocide at a concentration of 100 parts per million (ppm) by volume and then the aircraft pressure-refuelled using the onboard automatic control functionality in accordance with AMM Task 12-11-28-650-003-A, *Pressure Refuel with Automatic Control*. The Kathon-dosed fuel should remain in the aircraft fuel tanks for 24 hours.

The EASA Part-66 B1 licensed AMO engineer¹¹ was not familiar with the term 'ppm'. It was not written in expanded form anywhere in the AMM Task or glossary, and the AMM task did not provide instructions about how to perform the calculation of how much Kathon to use. He therefore searched the internet for a definition and conversion calculator. The AMO engineer knew that he would be uploading 6,200 kg of fuel into each wing tank and, using an internet calculator, he calculated a quantity of 30 kg of Kathon for each wing tank. There was 150 kg of Kathon available in the AMO stores and so he made a material requisition for 60 kg of Kathon.

To achieve a concentration of 100 ppm by volume, the following calculation should be made:

Fuel uplifted: 6,200 kg with a Specific Gravity of 0.808¹² = 7,678 litres

100 ppm = 0.0001

7,678 x 0.0001 = 0.768 litres of Kathon

Using a Kathon Specific Gravity of 1.04 = 0.799 kg per wing tank.

In the AMM there are four tasks for the shock treatment for moderate contamination: two tasks with Kathon biocide; and two with Biobor JF (Biobor), which is not currently registered for use in the European Union. For each biocide there is a task for mixing it with fuel prior to

Footnote

¹⁰ EASA Part M, AMC1 M.A.402(h) Performance of maintenance CRITICAL MAINTENANCE TASKS. <https://www.easa.europa.eu/sites/default/files/dfu/Annex%20I%20to%20Decision%202016-011-R.pdf> Accessed 07 April 2020.

¹¹ This engineer is referred to as the AMO engineer throughout the report.

¹² DEF STAN 91-091 Issue 11 states an allowable range of JET A-1 density at 15°C of between 775.0 – 840.0 kg/m³. For the purposes of the calculation used in this report, the mean of these allowable density values, 807.5 kg/m³, has been used. This mean value equates to a Specific Gravity of 0.808.

the mixed fuel then being uplifted to the aircraft, and a second, alternative, task for adding the biocide via a metering rig during the refuelling process. The manufacturer does not provide instructions for a method of mixing the biocide with fuel. The biocide dosing task was to be combined with the fuel tank leak check, and the AMO engineer responsible for the task used the overwing refuel aperture to add the Kathon¹³. The AMO engineer added 30 kg of Kathon to the left wing tank through the overwing aperture and a further 30 kg of Kathon to the right wing, also through its overwing aperture, whilst he uplifted 6,200 kg of fuel into each wing tank. The Kathon-dosed fuel, at 3,750 ppm (by volume), approximately 37 times the recommended dose, was left in situ for 24 hours in accordance with the AMM task, and the engine and APU fuel filters were changed.

The next day 6,400 kg of fuel was transferred from the wing tanks to the centre fuel tank and again left in situ for 24 hours. After this time the task card was stamped as complete, with a further task opened to perform a biological contamination check within 10 days but after at least 5 flights. The aircraft departed the AMO and returned to the operator's base on 24 February 2020.

Troubleshooting at Gatwick

After the aircraft arrived at Gatwick from Krakow, the operator's Technical Control instructed an EASA Part-66 B1 licensed engineer to attend the aircraft to troubleshoot the No 2 engine stall. The Gatwick engineer worked for an EASA Part-145 AMO that provided line maintenance at Gatwick for the operator.

The troubleshooting manual (TSM) was provided using the manufacturer's online system *AIRBUS World: AirN@v Maintenance*. This system included two different applications: *AirN@v* and *airnav^x* which was recently introduced to replace *AirN@v*.

The operator had granted the AMO access to the operator's data on *AirN@v* but not *airnav^x*, so the Gatwick engineer used *AirN@v* to try and access the applicable troubleshooting procedure. The design of *airnav^x* requires the user to filter data to a specific aircraft before going through the troubleshooting process but *AirN@v* does not. The Gatwick engineer did not filter the TSM for the specific aircraft registration, fleet serial number or effectivity for G-POWN but accessed the procedure using the TSM table of contents. In doing it this way, it was possible to access the procedures for all the operator's Airbus aircraft.

Airbus recommended that the TSM must always be filtered for a specific aircraft registration, fleet serial number or effectivity and that the TSM should be accessed using the '*Start Troubleshooting*' function in *AirN@v* (Figure 2) and the '*Troubleshooting*' tab in *airnav^x* (Figure 3).

Footnote

¹³ An optional modification was offered by the manufacturer to include an overwing refuel aperture to facilitate gravity refueling of the aircraft. This modification had been embodied on G-POWN and was fitted to both wings.

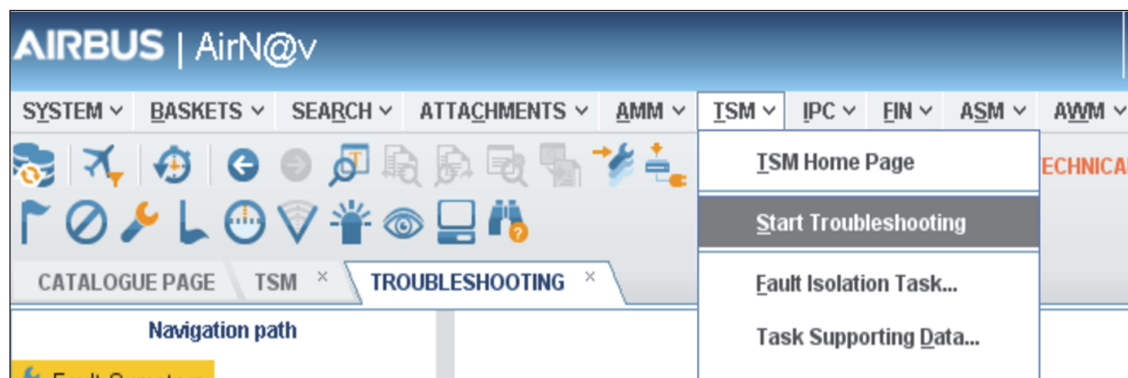


Figure 2

Airbus recommended way to access the TSM in AirN@v v3, 'Start Troubleshooting' function

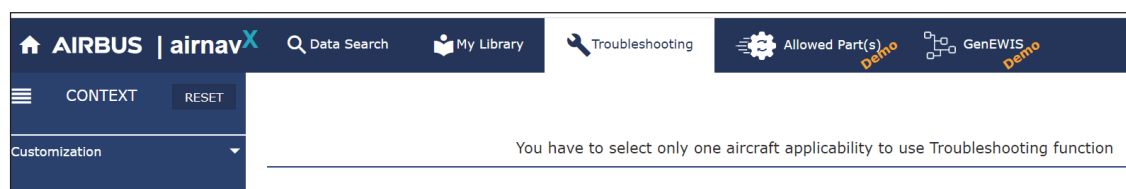


Figure 3

Airbus recommended way to access the TSM in airnavX, 'Troubleshooting' tab

The Gatwick engineer printed and followed TSM procedure 77-11-00-810-815-A, *Stall above idle on engine 1(2)*, which applied to LEAP-1A32 engines. However, G-POWN was fitted with the CFM56-5B3/3 engine and the applicable TSM procedure for this engine is 73-00-00-810-866-A, *Stall of engine 1 or 2 in flight*. This TSM procedure requires an extensive examination of the engine, including borescope inspections of the high pressure and Stage 1 low pressure turbine blades.

No fault was found during the troubleshooting, so the Gatwick engineer released the aircraft to service. The reasons why the Gatwick engineer selected the troubleshooting procedure for the LEAP engine, and any impact of this on the sequence of events in the subsequent serious incident will be investigated further.

Aircraft damage

Fuel samples

Following the serious incident, fuel samples were taken from the left and right wing fuel tank water drain valves and were subjected to laboratory analysis. When the fuel was tested it was found not to comply with the JET A-1 specification requirements¹⁴ for appearance

Footnote

¹⁴ DEF STAN 91-091 Issue 11 and AFQRJOS Check List Issue 31.

and water separation characteristics (MSEP¹⁵). The fuel samples, once the contents had settled out under gravity, contained a separate brown liquid layer beneath the main fuel layer (Figure 4). Trace element results of the fuel and the bottom brown layer showed similar spectra to a reference Kathon sample, but with a higher water content. The laboratory that conducted the fuel testing commented that:

'The results indicate contamination with undissolved Kathon. It was noted that the bottom layer that is mostly Kathon plus some unknown products and water, suspected to be causing the darker colour than the reference Kathon sample. This is likely due to the glycol type solvent used in Kathon product dissolving polar materials from the fuel and fuel tank surfaces. This may be analogous to observations with another similar glycol additive, FSII (Fuel System Icing Inhibitor), which is used in military jet fuels. It is colourless but forms brown additive/water layer in tank bottoms.'

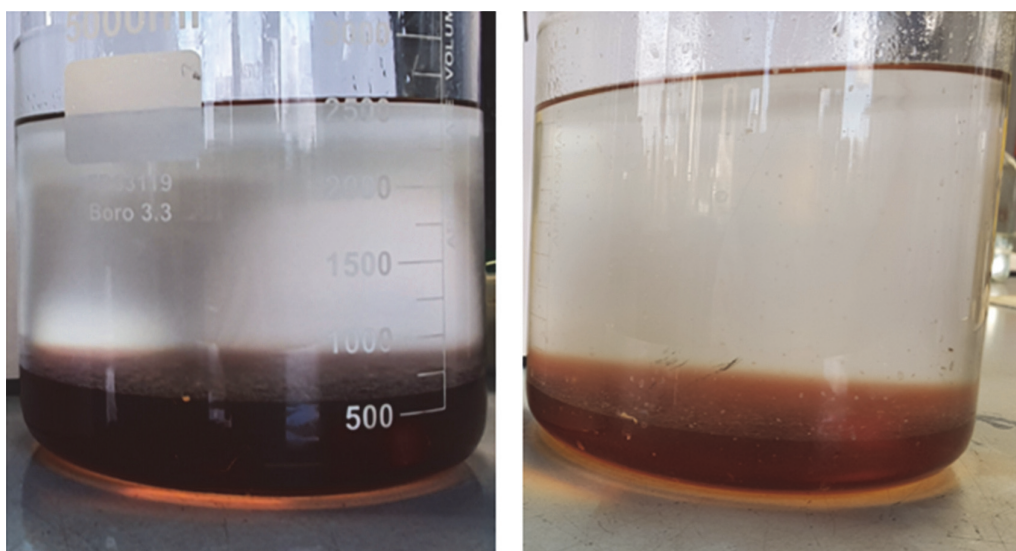


Figure 4

Fuel samples drained from left and right wing fuel tanks

The engines' fuel filter and filter bowl fuel samples were also analysed. The fuel filters were clean in appearance and generally free from debris, however chemical analysis of the small amount of filter debris present indicated unusually high levels of magnesium, a constituent element present in Kathon.

Footnote

¹⁵ Water Separator Index Modified (MSEP).

Engines

The aircraft's engines were examined visually using a borescope and both exhibited similar findings. There was no significant damage evident to the fan, low-pressure compressor or high-pressure compressor components, and any minor defects that were identified were within AMM damage limits. The combustion chambers, and high-pressure and low-pressure turbine blades were coated in a thin layer of white material that was observed on the turbine blades' convex surfaces (Figure 5). The high-pressure turbine nozzle guide vanes were also coated in the white material.



Figure 5

White material deposits on No 2 engine high-pressure turbine blades
(No 1 engine similar)

Significant deposits of a brown material were evident on all the combustion chamber swirl cups, adjacent to the fuel spray nozzles, in both engines (Figure 6).



Figure 6

Brown material deposits in No 2 engine combustion chamber swirl cups
(No 1 engine similar)

It was not possible to remove samples of the white and brown materials from within the engines at the time the borescope inspections were performed. Additional examinations are planned that will include inspection of the engines' fuel system components, including the hydromechanical units (HMUs).

Discussion

During biocidal shock treatment, an excessive quantity of Kathon biocide was introduced into the aircraft's wing fuel tanks, equating to 37 times the maximum permitted dosage in the AMM. The AMO engineer who carried out this task had not performed it before and did not recognise that he was using an excessive quantity of biocide. The task had not been designated as a critical task, and therefore no additional measures were used to check that it was performed in accordance with the AMM Task. The reasons for this and the impact on the sequence of events in the subsequent serious incident will be investigated. No control measures were in place at the AMO stores or planning departments to prevent unusually large quantities of chemicals being issued to AMO staff. In addition, the AMM task instructions used the term 'ppm' for which there was no definition within the AMM glossary, and no additional guidance was provided of how to perform the biocide fuel dosing calculation.

The biocide application method used was for a manually-calculated dose to be applied directly to the fuel tanks through the overwing aperture. This was not an approved process within the AMM. It was performed in this manner to enable the biocide application to be accomplished in the absence of a fuel metering cart or separate fuel bowser that would have allowed the biocide to be pre-mixed with fuel prior to pressure-refuelling the aircraft, as required by the AMM.

The excessive level of Kathon in the aircraft's fuel system is suspected to have caused the subsequent problems with the aircraft's engines, including those experienced during the incident flight. The AAIB is also aware of other events where engine performance was affected by over-dosing of fuel with biocide. Visual inspection confirmed the presence of abnormal deposits within both engines downstream of the fuel spray nozzles. The influence of the over-dosed fuel on the engines' HMUs and other fuel system components is subject to the ongoing AAIB investigation.

Before the incident flight, there were start-up difficulties with the No 1 engine and momentary ENG 2 STALL messages associated with the No 2 engine on descent into Gatwick. An engineer was tasked with troubleshooting the engine stall messages. This intervention was a potential opportunity to detect the abnormal deposits on the high pressure and low pressure turbine blades. It is considered likely that a borescope inspection would have detected these deposits and, had it done so, it is unlikely that the aircraft would have been released to service. The engineer was not tasked with investigating any issues with the No 1 engine. The symptoms presented by each engine were different and no one considered there to be a possible common cause.

When using the computer-based aircraft manual for troubleshooting, the Gatwick engineer did not filter the TSM for the aircraft he was working on and accessed troubleshooting procedures using the table of contents. This differed from the manufacturer's recommended method of using the TSM. Consequently, the engineer selected a procedure for a different type of engine to that fitted to G-POWN. The Gatwick AMO did not have access to the manufacturer's most recent computer based application for manuals, *airnav*^x, which is designed to ensure engineers filter the TSM for a specific aircraft. This later application would have reduced the chance of the engineer selecting the wrong procedure.

The Gatwick engineer followed the procedure he had selected, which did not require a borescope inspection, and found no fault, so he released the aircraft to service. The reasons why the incorrect procedure was selected, and the differences between this and the correct procedure, are part of the ongoing AAIB investigation.

Safety actions

Following this serious incident, the following safety action was taken:

Action by regulators

The EASA issued Safety Information Bulletin SIB 2020-06¹⁶ on 20 March 2020, to notify affected stakeholders of recent air safety-related events involving Kathon biocide and to remind aircraft owners and operators to ensure that the correct method and dosage is used for approved biocide treatment of aircraft fuel systems. The FAA issued Special Airworthiness Information Bulletin SAIB NE-20-04¹⁷ on 25 March 2020 that contained similar regulatory guidance.

Action by the manufacturers of the biocide and engines

The manufacturer of Kathon discontinued the use of its product for aviation fuel applications on 10 March 2020.

On 16 March 2020, CFM, the manufacturer of the G-POWN's engines, issued Alert Service Bulletin 73-A0296 recommending that operators of CFM56-5B engines suspend the use of Kathon during aircraft fuel system biocide treatments. Similar instructions were issued for other variants of the CFM56 engine family, as well as all General Electric turbofan engines.

Note: the discontinuation of Kathon for aviation applications, combined with the inability to use Biobor within the EU presently, leaves aircraft operators in the EU without an approved biocide treatment.

Action by the AMO that performed the biocide treatment

The AMO that performed the biocide treatment on G-POWN has introduced a new role of 'technical engineer'. The technical engineer will be an EASA Part-66 B1 licensed engineer, outside of the management chain within the organisation, who will be available to assist other licensed engineers and mechanics with technical queries, such as calculations.

The AMO will also introduce usage limits in stores so that staff will not be able to withdraw chemicals in quantities that significantly exceed the maximum permitted.

Footnote

¹⁶ <https://ad.easa.europa.eu/ad/2020-06> (accessed 9 April 2020).

¹⁷ [https://rgl.faa.gov/Regulatory_and_Guidance_Library/rgSAIB.nsf/dc7bd4f27e5f107486257221005f069d/05f721d6c7272c0986258536005bbe41/\\$FILE/NE-20-04_Corrected.pdf](https://rgl.faa.gov/Regulatory_and_Guidance_Library/rgSAIB.nsf/dc7bd4f27e5f107486257221005f069d/05f721d6c7272c0986258536005bbe41/$FILE/NE-20-04_Corrected.pdf) (accessed 9 April 2020).

Action by the Operator and the AMO at London Gatwick Airport

In consultation with the manufacturer, the operator granted the Gatwick AMO access to the airnav^x system.

The Gatwick AMO issued a safety and compliance notice highlighting the importance of filtering maintenance data to the specific aircraft.

Further work

The investigation will consider the relevant operational, technical, organisational and human factors which might have contributed to this serious incident. In particular, it will consider:

- a. Why the AMO procedures did not ensure that the biocide treatment was performed in accordance with the relevant AMM task.
- b. The influence of the over-dosed fuel on G-POWN's engine HMUs and other fuel system components.
- c. Why and how the troubleshooting procedure for the LEAP engine came to be used at Gatwick, and confirm what impact using the correct procedure might have had on subsequent events.

A final report will be published in due course.

Published: 21 April 2020.

AAIB investigations are conducted in accordance with Annex 13 to the ICAO Convention on International Civil Aviation, EU Regulation No 996/2010 and The Civil Aviation (Investigation of Air Accidents and Incidents) Regulations 2018.

The sole objective of the investigation of an accident or incident under these Regulations is the prevention of future accidents and incidents. It is not the purpose of such an investigation to apportion blame or liability.

Accordingly, it is inappropriate that AAIB reports should be used to assign fault or blame or determine liability, since neither the investigation nor the reporting process has been undertaken for that purpose.

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