Jurnal Integrasi
Vol. 18 No. 1, April 2026, 25-32
e-ISSN: 2548-9828

Article History
Received January 2026
Accepted April 2026

Case Study: Fuel Leakage in the Fuel Drain Area of the Tank Ejector on the Airbus A330-300 Engine

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Abstract

Fuel leaks in aircraft engines are a critical maintenance issue that can compromise flight safety and increase operating costs. This study aims to analyze the causes and resolve a specific case of a fuel leak classified as a stain (wet area diameter less than ¾ inch) on the fuel drains tank ejector area of the right engine (Engine 2) of an Airbus A330-300 PK-GHC aircraft. The methodology employed includes visual field observations and a review of technical documents based on Aircraft Maintenance Manual (AMM) 71-71-00-200-802-A and Troubleshooting Manual (TSM) task card 71-71-42-000-804-A. The investigation results showed that the leak was caused by structural damage to the left input connector. Corrective action was successfully executed by replacing the connector and installing a new seal ring (Part Number AS43013-131), followed by tightening the bolts to a torque specification of 90–110 lbf.in and the connector to 193.5–236.5 lbf.in. A post installation visual check confirmed that the system returned to normal operation with zero subsequent leaks. This case study provides a practical contribution by establishing that the connector on the fuel drains tank ejector is a critical component requiring regular preventive inspections, serving as a technical reference to prevent similar potential leak risks on wide-body aircraft fleets.

Keywords: Fuel Leakage, Fuel Drain System, Airbus A330-300, Aircraft Maintenance

1. Introduction

Fuel leaks in aircraft engines are a serious problem that can threaten flight safety and cause economic losses for operators [18]. These leaks have various causes, including damage to the fuel system—such as cracks in fuel pipes, damage to seals and valves, and corrosion of components—as well as human error during maintenance [1–4]. The impact of leaks is not only the loss of fuel, which reduces operational efficiency, but also the risk of fire or explosion, as well as structural damage to the aircraft. Therefore, a deep understanding of the causes and corrective measures for fuel leaks is crucial to ensuring flight safety.

In several global aviation incidents, fuel leaks in aircraft engines have led to serious consequences, ranging from engine fires, such as in the Garuda Indonesia Hajj incident, to unpowered emergency landings, such as in the case of Air Transat Flight 236. These incidents are often caused by a combination of mechanical component failures, maintenance errors, or design issues in the fuel control system, highlighting the risks of fire, structural damage, and significant potential loss of life [17,18].

A number of previous studies have highlighted the issue of fuel leaks in aircraft. Some studies indicate that the potential for leaks is influenced by fluid flow characteristics and the mechanical properties of the pipes [5,6], while analyses of fuel tank inerting systems emphasize the importance of controlling internal pressure for prevention [7,8,9]. On the other hand, leak detection methods have been developed through structural strength testing [10,11,12]. Other studies also confirm that leaks resulting from component degradation or maintenance errors have a direct impact on operational safety [13,14,15]. Although the issue of fuel leaks has been extensively studied, research specifically addressing fuel drain tank ejectors on wide-body aircraft remains very limited.

Figure 1 shows the block diagram of the Airbus A330 engine fuel system. As shown in the diagram, the fuel supply from the aircraft's fuel tank enters the engine fuel pump, controlled by the Low Pressure (LP) valve. The engine fuel pump itself consists of an LP fuel pump and a High Pressure (HP) fuel pump. Fuel from the aircraft's fuel tank is initially supplied to the LP fuel pump, which then directs it to the Fuel Oil Heat Exchanger (FOHE) to heat the fuel and cool the oil. The heated fuel then enters the LP fuel filter for filtration. Filtered fuel is subsequently directed to the HP fuel pump. The HP fuel pump pumps fuel to supply the Fuel Metering Unit (FMU), the Variable Stator Vane (VSV) actuator, and the modulating valve of the Air Oil Heat Exchanger (AOHE).

The metering valve in the FMU regulates the fuel flow directed to the combustion chamber. The fuel flow from the FMU passes through the fuel flow transmitter and the high-pressure fuel filter before supplying the fuel manifold and the fuel spray nozzle. Inside the FMU is a Pressure Raising and Shut-Off Valve (PRSOV). This valve can be opened to initiate fuel flow or closed to stop the fuel flow completely and maintain the fuel at the correct pressure. Inside the FMU there is an overspeed valve that can close the PRSOV in the event of excessive speed in the N1, N2, or LP turbine. Before the engine is started, the master switch is turned off, and the LP valve and PRSOV are closed. When the master switch is turned on,

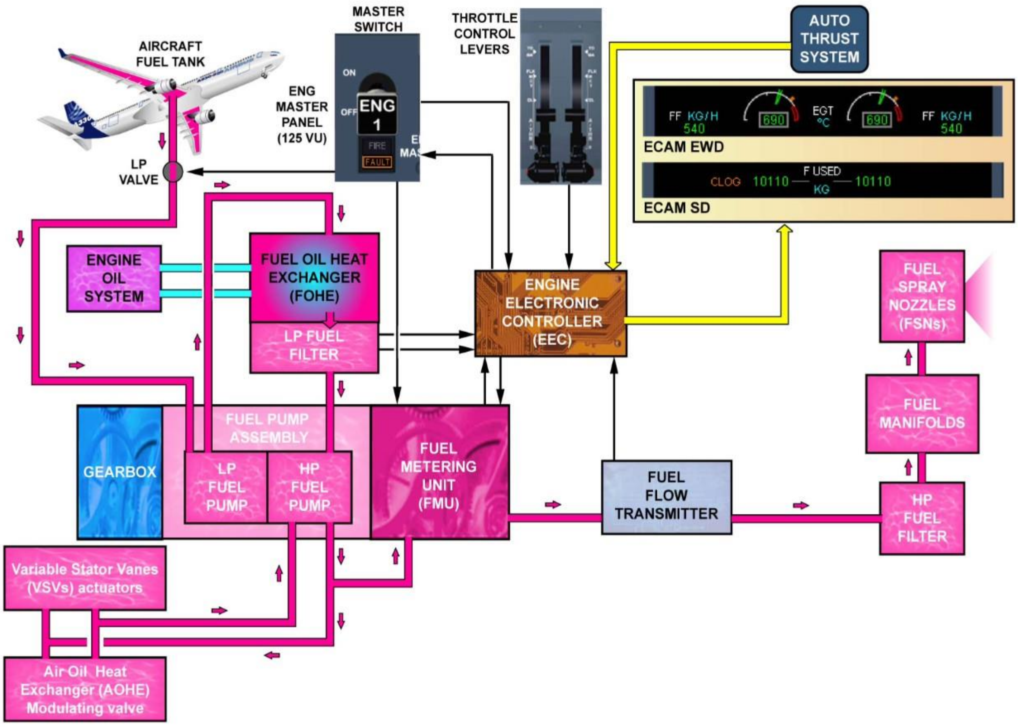


Figure 1. A330 Engine Fuel System Block Diagram

the LP valve opens and the PRSOV is controlled and opened by the Electronic Engine Control (EEC). The EEC controls the fuel flow through the metering valve in response to the throttle control lever or commands from the auto-thrust system. Normal engine shutdown is performed by setting the master switch to 'off', which directly closes the LP valve and the PRSOV.

The EEC can also automatically shut down the PRSOV in the event of an automatic start abort on the ground. To monitor the fuel system and the Electronic Centralised Aircraft Monitor (ECAM) indicators, the EEC uses sensors such as the fuel flow transmitter, the LP fuel filter differential pressure switch, and the fuel low pressure switch.

The drainage system plays a crucial role in removing various types of unwanted fluids from the engine area and its supporting structures (pylons). Figure 2 shows a block diagram of the

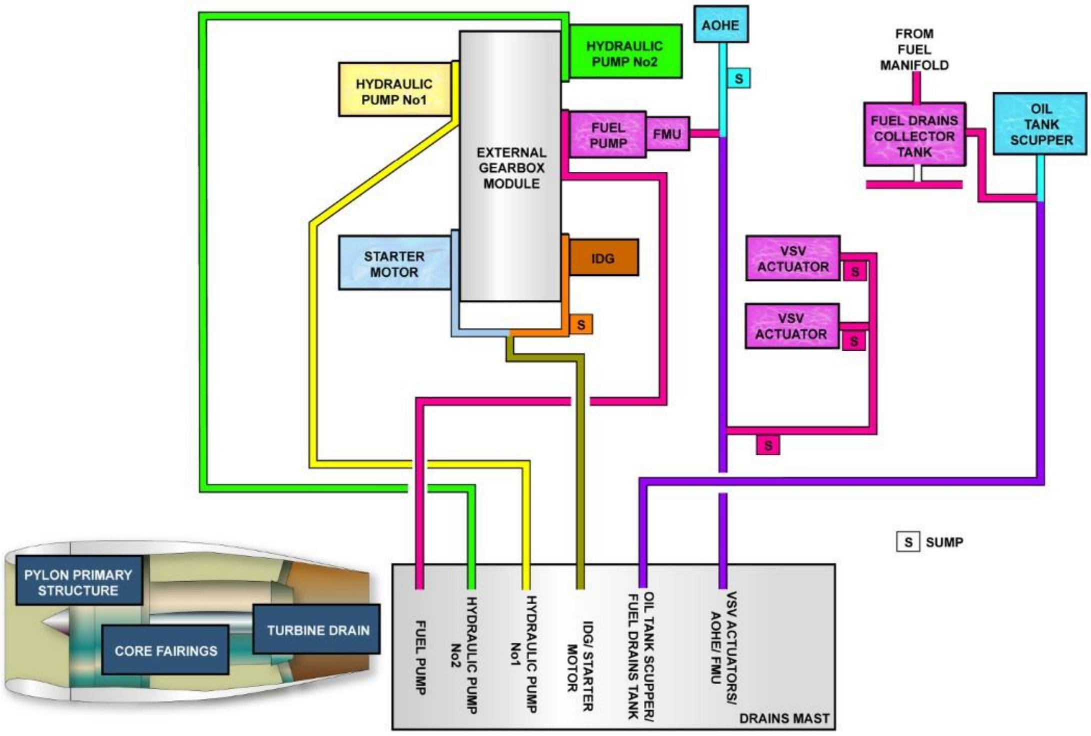


Figure 2. A330 Engine Fuel System Block Diagram

engine drainage system on the Airbus A330. Primary tasks of the engine drainage system can be divided into three: firstly, draining internal leaks such as fuel or oil. Secondly, removing external fluids that have accumulated within the pylon, cowl and fairing. Thirdly, collecting unburned fuel residue from the combustion chamber after the engine has been shut down or if the start-up procedure fails. These internal leaks originate from various engine components and accessories connected to the drainage system, such as the AOHE, hydraulic pumps, LP/HP fuel pumps, FMU, pneumatic starter, Integrated Drive Generator (IDG), VSV actuator, and oil tank. All fluids from these components are safely drained out of the aircraft via the main drainage line known as the drains mast. To facilitate leak detection, several critical components such as the VSV actuator, AOHE, and IDG have individual drain tubes, although many of them are also connected to the same drain line on the drains mast. In addition to dealing with component leaks, this system also features separate drains for removing fluid from the main pylon structure and the area around the LP turbine. Figure 4 shows the Mast Drains and Fuel Drains Collector Tank on an Airbus A330-200.

According to AMM 71-71-00-200-802-A, the drain system is a fuel collection system designed for when the engine stops running or fails to start properly. A schematic diagram of the drain system as per the AMM is shown in Figure 3. This system collects fuel and returns it to the fuel pump for reuse. If there is an excess of fuel or unwanted liquid, this system can also safely discharge it, thereby eliminating the risk of engine fire whilst the engine is running or after it has been shut down. This includes the discharge of any liquid that may have accumulated in the pylon and nacelle areas. The drains system itself comprises a fuel drains collector tank, which collects fuel when the engine is shut down. This tank also collects fuel flowing from the fuel manifold. When the engine restarts, the fuel drain tank ejector pumps the collected fuel back into the HP fuel pump inlet. If the collector tank becomes too full, it also has a connection to the fuel drain tank ejector to discharge excess fuel. Furthermore, the drain system is equipped with a drain mast connected to specific areas of the engine via tubes, allowing fluids to flow from these areas and helping to prevent potential engine fires. Components of the drains system are the fuel drains collector tank, drains mast, pylon, LP compressor case zone drain, forward core zone drain, rear core zone drain, and turbine wet start drain. The fuel drains collector tank is a cylindrical component mounted with a bracket to the external gearbox. This tank is designed with a capacity to hold fuel drained from the engine during one engine shutdown and three failed engine start-ups. At the top of the tank are two fuel pipes secured with bolts. One of these pipes originates from the fuel manifold via the Hydro-Mechanical Unit (HMU). A Non-Return Valve (NRV) is fitted between the ejector and the tank. The NRV ensures that backflow of fuel from the LP supply does not enter the tank. This can occur when the fuel system is pressurised by the aircraft's fuel pump whilst the engine is not operating. At the bottom of the tank is a float valve that ensures air does not enter the LP fuel pump supply when the tank is empty. The other pipe connects the tank to the drain mast. At the bottom of the tank are fuel drain ejectors secured with bolts. Whilst the engine is running, fuel flows continuously through the ejectors. Fuel flowing into the fuel drain collector tank is also directed to the LP fuel pump inlet by the fuel drain ejectors as long as there is fuel in the tank.

The classification of fuel leaks on aircraft is a crucial standard procedure for determining the level of urgency and the appropriate maintenance action. Based on observations over a 30-minute period, these leaks are divided into four levels according to the size of the area wetted by fuel. The mildest level is called a stain, defined as a wet area with a diameter of less than ¾ inch. The next

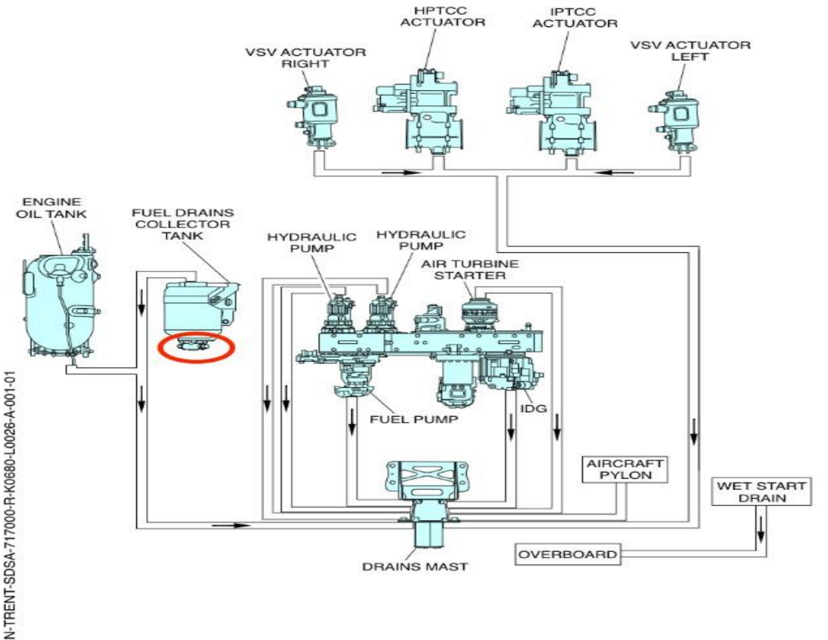


Figure 3. Engine Drains System Schematic A330

category is a seep, where the wet area formed has a diameter of between ¾ and 1½ inches. If the seep becomes more significant and covers an area with a diameter of between 1½ and 4 inches, the leak is classified as a heavy seep. Finally, the most severe and urgent category is a running leak. At this level, the fuel no longer merely wets the surface but is clearly seen to be flowing, pooling, and dripping from the aircraft structure and can spread over a considerable distance. An accurate understanding of each of these categories is crucial as it will determine whether the aircraft requires scheduled monitoring, immediate repair, or is even declared unfit to fly (no-go).

Given this urgency, this study focuses on resolving a real-world problem involving a fuel leak classified as a 'stain' (wet area diameter less than ¾ inch) in the fuel drain area of the ejector tank on the right-hand engine (Engine 2) of the Airbus A330-300 aircraft PK-GHC. This study aims to definitively identify the root cause of the damage, formulate corrective measures based on AMM and TSM guidelines, and validate the success of the corrective actions. Through the analysis of this case study, it is hoped that the resulting findings will serve as a practical technical reference and preventive measures for maintenance personnel in mitigating the potential risk of similar leaks, thereby ensuring that aviation operational safety standards are maintained.

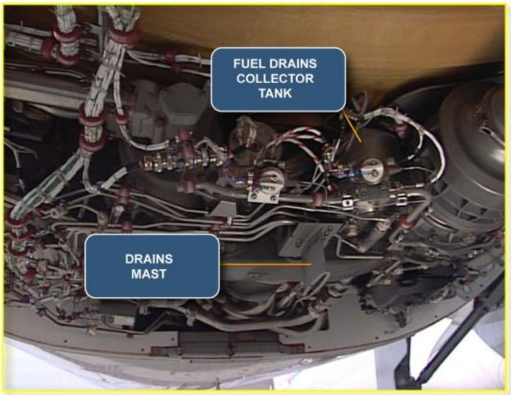


Figure 4. Mast Drains & Fuel Drains Collector Tank

2. Research Methodology

This research method was systematically designed using a descriptive qualitative approach focusing on aircraft maintenance troubleshooting techniques. Data collection was classified into two types: Primary Data, which is data obtained through specific field observations in the form of visual checks when the aircraft is in Remain Over Night (RON) status. These observations identified the extent of fuel leaks to classify the severity of the leak (stain categories with a diameter of less than ¾ inch) and determine the location of the faulty component. Secondary data was also utilised, comprising information from the aircraft's Technical Log (Swift) and technical literature from the manufacturer, which was used hierarchically as the basis for analysis.

The technical documents are used sequentially. Firstly, the TSM is used as the basis for fault isolation analysis to eliminate other potential causes and narrow the problem down to a specific connector. Secondly, the AMM is used as the standard operating procedure for the rectification stage (removal and refitting). Finally, the Air Transport Association (ATA) Technical Training Manual, Chapter 71: Powerplant, is used to provide a comprehensive context regarding the operation of the engine drain system. The stages of this research are presented in a flowchart, namely Figure 5.

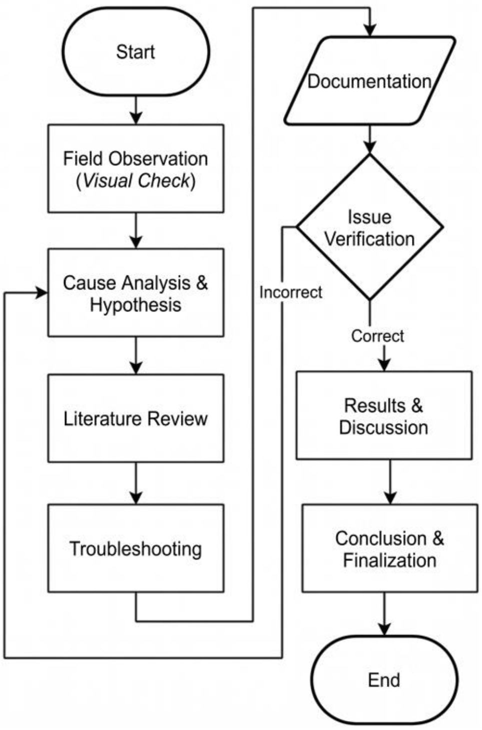


Figure 5. Research Process Flowchart

This troubleshooting process begins with a field observation stage, during which fuel leaks are identified through a careful visual inspection. The primary focus is on vulnerable areas such as the joints between fuel lines or where the lines meet components, including the possibility of internal leaks within the components themselves. The analysis techniques and troubleshooting procedures in this study were adapted from aircraft maintenance investigation standards. This stage begins with Fault Identification (specific observation) through a visual check of areas prone to leaks, particularly at the fuel line joints in the engine drain system. Next, the process moves to Fault Isolation (cause analysis), where the problem is not identified through guesswork but by directly referring to the Technical Service Manual (TSM) to evaluate various failure scenarios (possible causes), such as seal wear, loose connectors, or structural damage to the O-ring. Once the root cause was confirmed to be the left-hand input connector, the Defect Rectification (repair) stage was immediately carried out by replacing the component. This procedure applied technical parameters of absolute precision based on AMM references, which included draining residual fuel, replacing the seal ring, and applying standard tightening torque. This investigation sequence was then concluded with an

Operational Check or Leak Check as the final validation step through system functionality testing; the aim was to ensure the issue had been resolved (zero leak) before the aircraft was declared serviceable again, and should this test fail, the procedure would be repeated (iterated) back to the Fault Isolation stage. Once an effective solution has been identified and implemented, the investigation concludes with a comprehensive review of the results achieved, the drawing of conclusions, and the finalisation of all documentation as a final report.

3. Results and Discussion

Figure 6. Fuel leak

This study was conducted following the discovery of a fuel leak on the Airbus A330-300 aircraft PK-GHC, which was detected whilst the aircraft was on the ground. The leak occurred in the fuel drain tank ejector area, which forms part of the engine drain system. This system functions to collect and discharge fuel or unwanted fluids from the aircraft engines to prevent operational issues or fire risks. Referring back to Chapter 1, the fuel drain tank ejector, which is located beneath the fuel drain collector tank and secured with bolts, serves to channel fuel from the fuel collector tank to the LP fuel pump whilst the engines are running. This ejector operates by utilising the pressure difference between the engine manifold and the fuel tank to draw residual fuel from the manifold into the tank. Additionally, the ejector is fitted with a check valve or NRV to prevent fuel from flowing back into the tank when the system is switched off. Components of the fuel drain tank ejector include a connector, seal ring, bolt, and bracket. This ejector has two connectors, one on the left and one on the right.

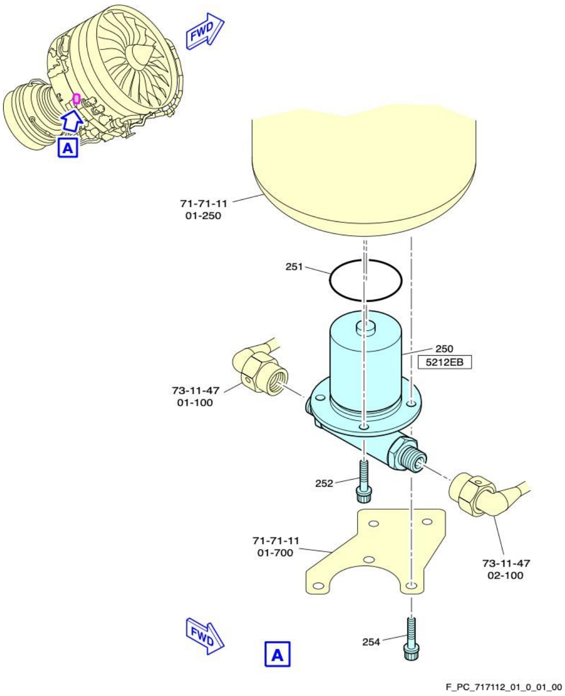


Figure 7. Fuel Drains Tank Ejector Schematic

The initial investigation involved a thorough visual inspection of the two main connection points on the fuel drain tank ejector. The observations revealed a stain-type leak with a wet area less than half an inch in diameter, specifically isolated to the left-hand input connector, whilst the right-hand connector was confirmed to be in normal condition with no signs of seepage. Figure 6 shows the fuel leak. Qualitatively, the degradation of the left-hand connector indicates a reduction in mechanical structural integrity, resulting in the seal ring no longer being able to withstand fluid pressure optimally. The subsequent troubleshooting process to remove and replace this component presents its own challenges in the field, particularly regarding the extremely limited working space beneath the fuel drain collector tank, which makes it difficult to manoeuvre tools such as a torque wrench to achieve precise torque. Furthermore, technicians must manage the remaining aviation fuel with the utmost care, using specialised collection

containers to mitigate the risk of exposure to flammable materials and prevent contamination in the work area

whilst the connector is being removed. According to TSM 71-71-00-810-801-A, in the event of a leak, the procedure to follow is to remove and reinstall the fuel drain tank ejector. Figures 7 and 8 show a schematic of the fuel drain tank ejector for reference during the connector removal process.

The next stage involves the removal and installation of the Fuel Drain Tank Ejector components. The main tools and materials required for this process include a clean collection container, a wrench, a torque wrench, a new seal ring with part number (P/N) AS43013-131, and a lock wire for safety. The work process comprises two main tasks. First, the removal stage (Task 71-71-42-000-804-A), which begins with positioning a container to collect any remaining fuel. The connector is detached from the ejector whilst holding the valve adapter in place using a wrench. Figure 9 shows the fuel being collected in the container. Figure 10 shows a technician removing the connector.

Figure 9. Documentation of the fuel that has been collected

Once the fuel has been drained, the retaining bolts are loosened and the used seal ring is removed and discarded. As a safety measure, all openings are covered with protective covers. Secondly, the installation stage (Task 71-71-42-400-804-A) begins by removing the protective cover. A new seal ring (P/N AS43013-131) is fitted to the ejector before the component is repositioned on its bracket. The bolts are tightened to a standard torque of between 90 and 110 lbf.in (1.02 and 1.24 m.daN). Next, the connector is connected and tightened to a torque of between 193.5 and 236.5 lbf.in (2.19 and 2.67 m.daN). The procedure is completed by fitting a locking wire to the connector to ensure the connection is securely fastened and does not come loose.

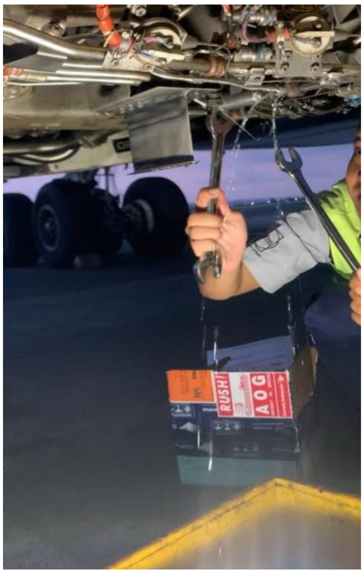


Figure 10. Connector Removal Documentation

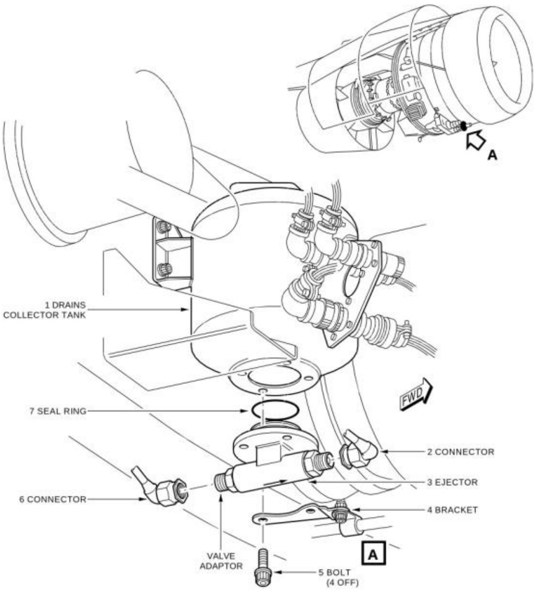


Figure 8. Fuel Drains Tank Ejector

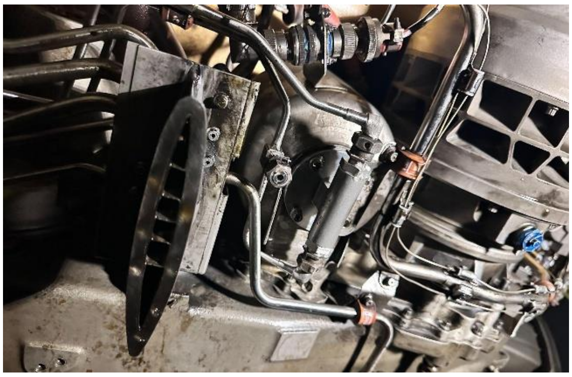
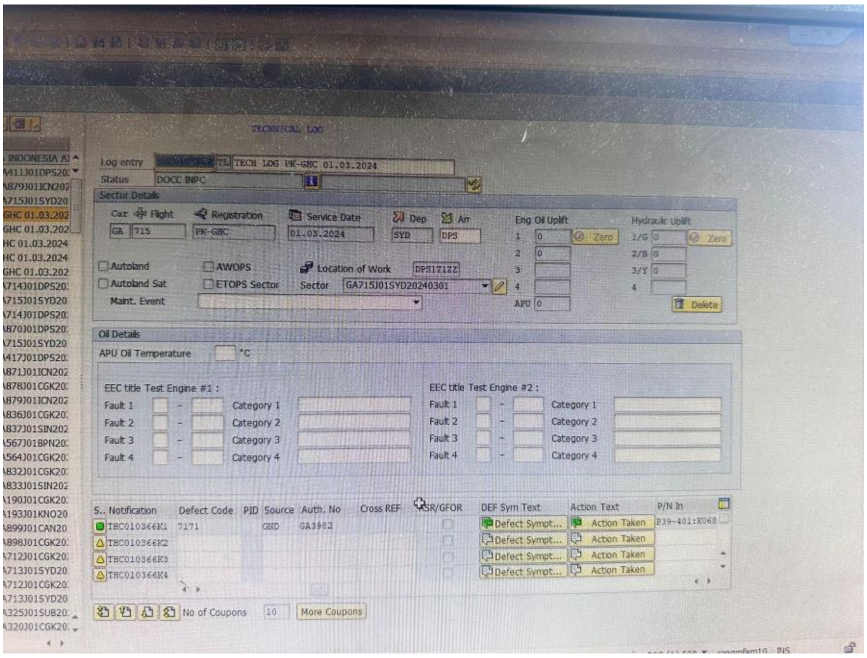


Figure 11. The Replaced Connector and the Fuel Tank Ejector After Reinstallation

The final step is to enter the Swift code as part of the aircraft data that has been processed, as shown in Figure 12. Damage to the fuel drain connectors on the ejector tank directly disrupts the optimal cycle of the engine drain system, whereby fuel that should be drawn from the collector tank to the LP fuel pump becomes blocked and instead accumulates. This accumulation of uncirculated fluid creates pressure anomalies and increases the risk of leaks escalating into active pooling, a condition consistent with previous literature which confirms that physical component degradation is a major contributor to fuel system failures that have fatal implications for operational safety. The corrective findings in this case also reinforce studies on preventive maintenance, wherein the



TECHNICAL LOG

Log entry [redacted] TL TECH LOG PK-GHC 01.03.2024
Status DOCC INPC

Sector Details
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☐ Autoland ☐ AWOPS · Location of Work DPS1T1ZZ
☐ Autoland Sat ☐ ETOPS Sector · Sector GA715J01SYD20240301
Maint. Event
Eng Oil Uplift: 1 0 · 2 0 · 3 · 4 · APU 0
Hydraulic Uplift: 1/G 0 · 2/B 0 · 3/Y 0 · 4

Oil Details
APU Oil Temperature °C

S..	Notification	Defect Code	PID	Source	Auth. No	Cross REF	SR/GFOR	DEF Sym Text	Action Text	P/N In
🟩	THC010366K1	7171		GND	GA3982		☐	Defect Sympt...	Action Taken	P39-401:K068
△	THC010366K2						☐	Defect Sympt...	Action Taken	
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No of Coupons 10

Figure 12. *Swift Technical Log* A330

application of precise bolt tightening torque standards and the replacement of new seal rings directly eliminate fluid pressure crack points. The resolution of this operational issue demonstrates that the fault isolation method—combining visual inspection with strict adherence to the manufacturer's manual—is highly effective in restoring the reliability of wide-body aircraft hydromechanical systems, thereby measurably reducing the potential risk of engine fires, as frequently examined in past aviation incidents. To address this issue, the fuel drain tank ejector connector must be replaced in accordance with the maintenance procedures for the Airbus A330-300 PK-GHC. Once the repair is complete, a visual check is carried out again to ensure that the leak has been resolved.

4. Conclusion

Based on the investigation into the Airbus A330-300 aircraft PK-GHC, the fuel leak classified as a 'stain' in the fuel drain area of the right engine's ejector tank was definitively caused by mechanical structural damage to the left-hand input connector. The corrective action undertaken—involving the replacement of the connector and the installation of a new seal ring (P/N AS43013-131), in full compliance with the manufacturer's standard tightening torque specifications—has been comprehensively successful in eliminating the leak point and restoring the reliability of the engine drainage system. In practical terms, the success of this repair provides direct benefits in mitigating the potential escalation of the leak into an active pool of fuel—which is prone to triggering engine fire incidents—whilst minimising the airline's losses resulting from the aircraft being grounded.

As a preventative measure for the future, it is strongly recommended that maintenance personnel incorporate more intensive visual inspections and periodic torque verification of the fuel drain tank ejector connectors, particularly when the aircraft undergoes RON maintenance. For further research, an analysis of the degradation rate of the seal ring material due to prolonged exposure to fluid pressure and thermal stress could be conducted to predict the service life of the component more accurately. Ultimately, this case study makes a significant contribution to the field of aviation maintenance by providing validated technical problem-solving guidelines, whilst reinforcing the evidence that a disciplined approach to investigations based on TSM and AMM is key to ensuring the operational safety of wide-body aircraft.

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