



Australian Government

Australian Transport Safety Bureau

Engine failure involving Saab 340B, VH-RXX

Near Merimbula, New South Wales on 29 August 2019

ATSB Transport Safety Report
Aviation Occurrence Investigation
AO-2019-046
Final – 13 August 2020

Released in accordance with section 25 of the *Transport Safety Investigation Act 2003*

Publishing information

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Addendum

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Safety summary

What happened

On the evening of 29 August 2019, a Regional Express Saab 340B, registered VH-RXX, departed Moruya, New South Wales. The aircraft was performing a scheduled passenger service to Merimbula, New South Wales. At the time, the aircraft's right engine was being monitored for high oil consumption.

Soon after top of climb, the flight crew received an engine fire indication from the right engine. While conducting the engine fire checklist, the engine surged and then failed. A cabin crew member reported seeing a brief flash of light from the right side of the aircraft. The flight crew then shut the engine down.

Based on the close proximity to the destination, the flight crew decided to continue to Merimbula Airport. The aircraft landed without incident at about 1950.

What the ATSB found

The engine failed as a result of an internal oil fire, which weakened a turbine disk and resulted in turbine blades being released. The fire occurred when oil leaked from an oil sump due to carbon deposits, known as coking, within that oil sump. The coking was most likely due to either the component not being completely clean when installed at the last major overhaul and/or accelerated coking on the component.

What's been done as a result

The engine manufacturer has enhanced the troubleshooting procedures to identify internal engine oil leaks more effectively and developed enhancements to the overhaul facility cleaning procedure for the affected oil sump.

Safety message

This incident highlights the importance, when piloting multi-engine aircraft, of maintaining the ability to operate with one engine inoperative. Aircraft turbine engines are complex, and can fail for reasons that are rare and difficult to identify prior to the failure. In this occurrence, the maintainers had followed the correct troubleshooting procedure but were unable to determine the reason for the high oil consumption. The crew's skill and knowledge, however, along with the built-in redundancies of the system ensured the overall safety of the flight.

The occurrence

What happened

At 2000 Eastern Standard Time¹ on 29 August 2019, a Regional Express Saab 340B, registered VH-RXX, departed Moruya, New South Wales. The aircraft was performing a scheduled passenger service to Merimbula, New South Wales. The flight was expected to take about 20 minutes.

Approximately 8 minutes into the flight, and shortly after levelling off at an altitude of 9,000 ft, the flight crew received an engine fire indication from the right engine. In response, they commenced the memory items² for the associated checklist. While conducting the first item on the checklist—reducing the power lever—they heard the engine surge and then produce a loud bang. The cabin crew member reported seeing a brief flash of light from the right side of the aircraft. The flight crew continued the Engine Fire checklist and subsequently shutdown the right engine.

Due to the close proximity to the destination, and with the aircraft already having been set up for the approach, the flight crew decided to continue to Merimbula Airport. A hold was established at a waypoint in order to allow the flight crew to complete all the required checklists, and to ensure the availability of emergency services at the destination.

At about 2040, the aircraft commenced the final approach to Merimbula. It landed without incident 7 minutes later.

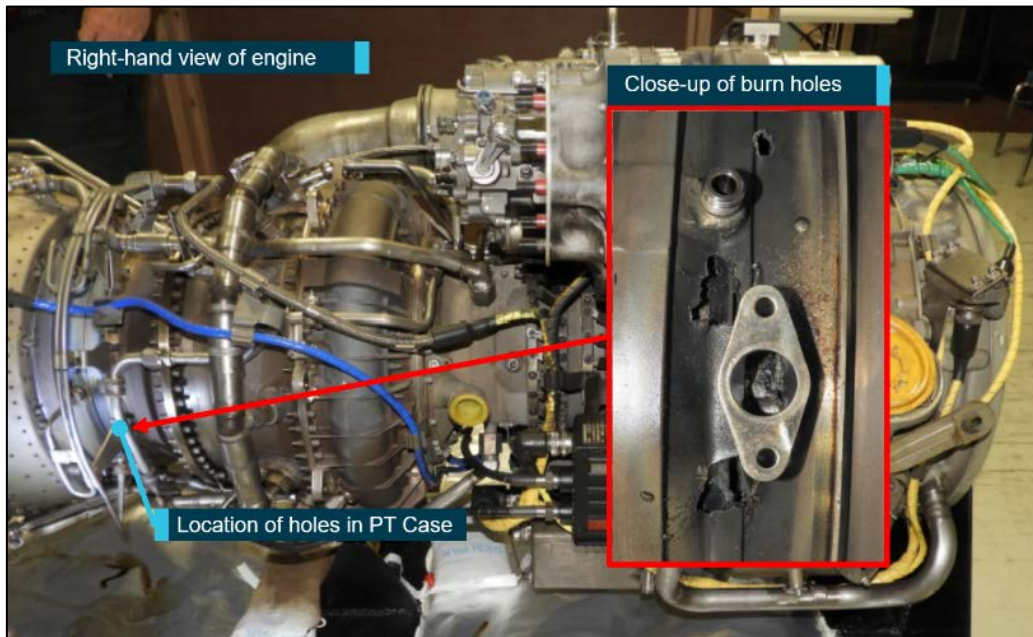
A post-flight visual examination of the engine revealed that there were several small burn holes³ in the power turbine (PT) case (Figure 1) and that the C-sump assembly and a section of the PT shaft were missing (Figure 2). The engine had previously undergone unscheduled maintenance for elevated oil consumption.

¹ Eastern Standard Time (EST): Coordinated Universal Time (UTC) + 10 hours.

² Memory items are checklist items required to be committed to memory to allow an immediate response to high-priority abnormal events such as engine fire or failure.

³ Burn holes are caused by hot gases above the melting temperature of the material. This is evidenced by the metal spatter around the holes and there being no direct path into the internal PT case.

Figure 1: Right-hand view of engine with burn holes indicated



Source: GE – annotations by ATSB

Figure 2: Rear-view comparison of undamaged engine (left) and the occurrence engine missing the C-Sump Assembly (right)



Source: GE – annotations by the ATSB

Context

Engine information

The engines fitted to VH-RXX were General Electric (GE) CT7-9B turboprop engines. At the time of the occurrence, the right engine, serial number ESN 785398, had accumulated 37,854.4 hours and 42,877 flight cycles since new.

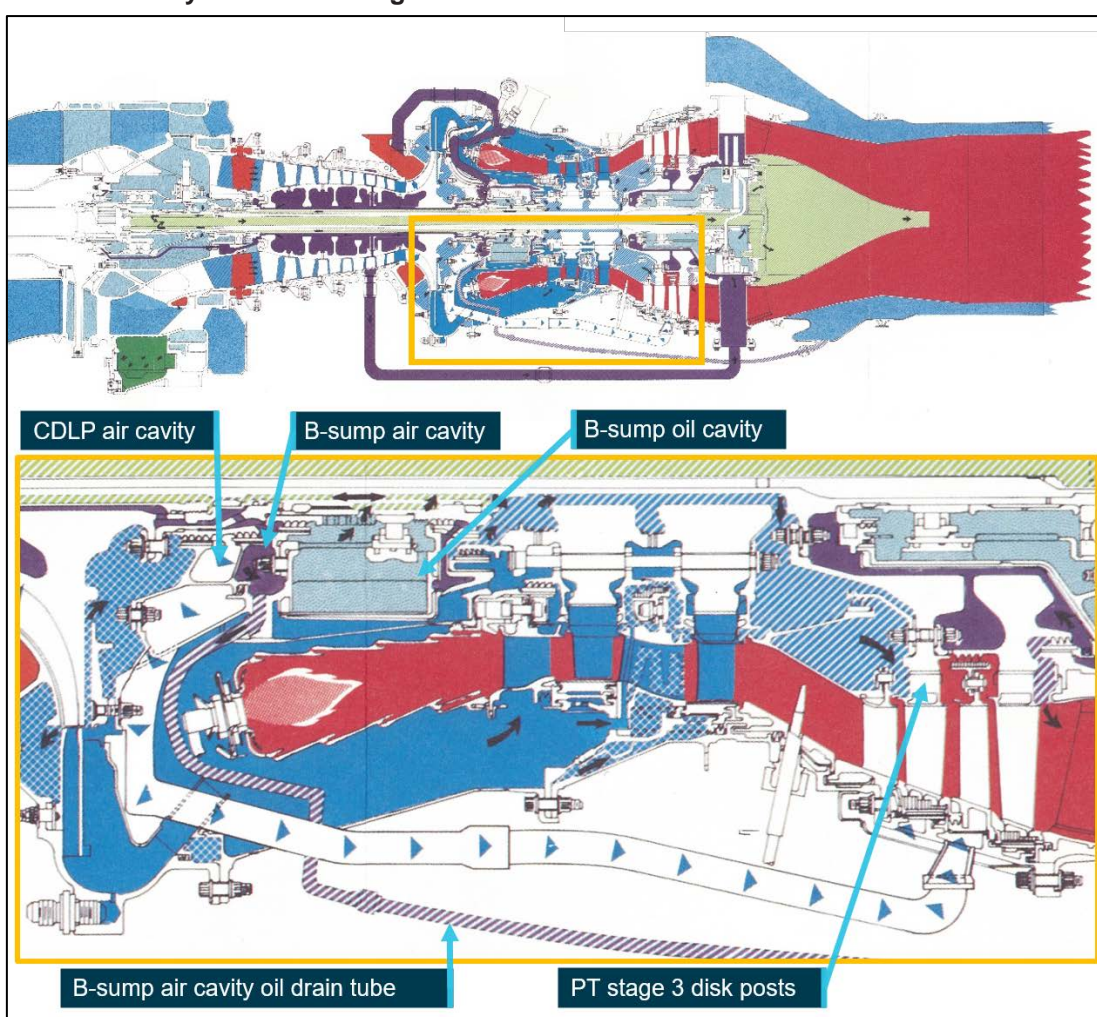
The CT7-9B consisted of a modular power unit and a propeller gearbox. The modular power unit comprised the:

- accessory module - driving engine accessories (e.g. starter, fuel pump, oil pump)
- cold section module - including the compressor and the midframe assemblies

- hot section module – including the combustor and the gas generator turbine
- power turbine module – transmitted power from the power turbine to the output shaft and into the propeller gearbox.

Located within the cold section module and part of the midframe assembly was the B-sump. This supplied oil to the bearing that supported the gas generator. A labyrinth seal⁴ separated the B-Sump oil cavity and the B-sump air cavity (Figure 3). During normal operation, it was possible for oil to leak beyond the labyrinth seal and accumulate within the B-sump air cavity. A drain tube incorporated into the cavity was intended to direct any oil from the B-sump air cavity into the exhaust gas path. Another labyrinth seal separated the B-sump air cavity from the compressor discharge leakage pressure⁵ (CDLP) air cavity. Oil was not intended to accumulate within the CDLP cavity.

Figure 3: Cross-section diagram of the CT7 – zoom showing the B-sump in relation to the CDLP air cavity and the PT stage 3 disk.



Source: CT-7 Training Manual – Annotated by the ATSB

Maintenance information

In May 2018, at 36,366.7 engine hours (41,144 cycles), 1,481 flight hours before the occurrence, a major workscope⁶ was conducted on the cold section of the engine at an approved engine

⁴ A labyrinth seal is a type of mechanical seal that provides a tortuous path to help prevent leakage of oil.

⁵ The compressor discharge leakage pressure air provides cooling air to the power turbine.

⁶ A workscope is a defined series of maintenance tasks performed on an engine.

overhaul facility in the United Kingdom. The previous major workscope was conducted about 14,000 flight hours prior.

As part of that workscope, the midframe assembly (which included the B-sump) was replaced with a refurbished component. Prior to installation, the components were cleaned in accordance with the latest GE procedure. Due to the design of the midframe, there was no visual means to inspect the B-Sump oil cavity in order to confirm complete removal of any coking (see the associated section below). Assurance that the part was clean was provided by means of a repeated flushing technique until there was no further debris found on a filter within the fluid path.

On 30 May 2019, the maintainers began troubleshooting the engine for high oil consumption. The maintainers followed the most current manufacturer's guidance for fault isolation of oil consumption issues, but were unable to identify the cause of the oil consumption issue.

Manufacturer's findings

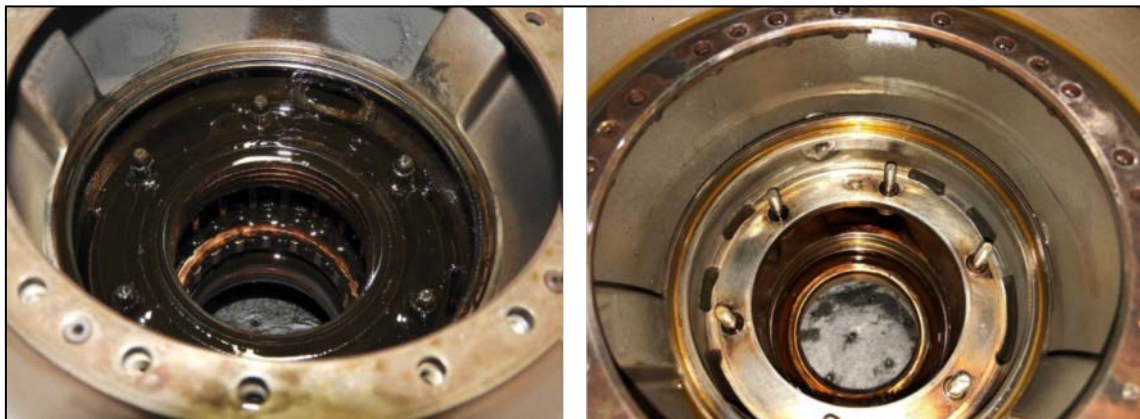
GE reviewed all available flight and engine data from prior to the failure and found that the engine had been operated in accordance with their prescribed recommendations.

The engine was transported to the GE Strother facility in the United States for a teardown and detailed examination supervised by the National Transportation Safety Board. The examination found that:

- the B-Sump oil cavity and the B-sump air cavity were heavily coked (Figure 4)
- the B-Sump oil drain was coked and blocked at the time of disassembly
- there was minor presence of coking and oil in the CDLP cavity
- a number of the power turbine (PT) stage 3 disk blades had been released. Examination of the remaining disk post tangs showed elongation and hardness values consistent with a creep condition as a result of exposure to elevated temperatures.

Conclusions of the analysis were that heavy coke build-up in the B-sump oil cavity resulted in the sump flooding⁷ and oil leaking into the B-sump air cavity. Due to the blocked B-sump air cavity oil drain tube, oil leaked into the CDLP air cavity. An oil fire then occurred in the CDLP air cavity and at the stage 3 outer diameter near the disk posts. This weakened the disk posts, and resulted in several blades being released. The resulting imbalance caused the separation of the section of PT shaft and the C-sump.

Figure 4: The coking within the B-sump of the occurrence engine (left) in comparison to the condition of a typical engine (right).



Source: GE

⁷ Flooding is the presence of excessive amounts of oil within the sump.

Coking

Coking is an artefact from exposure of oil to abnormally high temperatures that leads to oxidation and chemical breakdown of the oil. Coking can form as a thin-film layered deposit or in thicker clumps. Determining the initiating source of coke formation is difficult, as it can be attributed to a combination of influences, including:

- operational conditions such as hot shutdown
- design traits such as abrupt changes in oil flow direction and areas of low fluid velocity that can lead to reduced oil flow rates
- low-drainage areas resulting in conductive or convective oil temperature increases post shutdown
- reductions in cross-sections such as scavenge ports that increase the likelihood of blockage
- prolonged aircraft inactivity leading to moisture absorption of coke deposit.

Related occurrence

In 2005, a SAAB 340B fitted with a CT7-9B (ESN 785179) (not operated by Regional Express) sustained an in-flight shutdown determined to be due to B-Sump oil leaking into the CDLP air flow and igniting just forward of the PT stage-3 nozzle. Analysis of that engine also found heavy coking of the B-sump oil cavity and a blocked B-sump air cavity drain tube.

As a result of that occurrence, GE made several changes to improve the effectiveness of the procedure for cleaning the midframe, and modified the oil consumption fault isolation procedures with the intent of better identifying B-Sump leak issues.

Safety analysis

The engine failure involving Saab 340B VH-RXX, on 30 August 2019, was initiated by heavy coking in the B-Sump oil cavity, which resulted in oil leaking from the B-Sump and eventually causing an internal oil fire. This over-temperature condition weakened the PT stage 3 disk posts sufficiently to allow some turbine blades to be released, resulting in an imbalance and subsequent fracture of the PT shaft. The engine fire indication received by the flight crew was the result of hot gases being released through the burn holes in the PT case activating the fire-detection system.

The B-sump component had only completed 1,481 flight hours since it was installed on the engine in May 2018. This represented only about 10 per cent of the typical time between major worksopes. The high level of coking found in the B-sump could only have occurred in that timeframe if:

- the component was not completely clean on installation following the major workscope
 - there was an accelerated formation of coking within the component
- or a combination of both.

Despite the part being cleaned in accordance with the manufacturer's recommendation, it was not possible to inspect the oil cavity of the B-sump visually to confirm complete removal of coking. In addition, if any coke deposits were remaining within the component, this could have affected the oil flow and cooling within the sump, and contributed to further coking.

The manufacturer advised that there was no evidence that the engine was operated outside their recommendations, and so it is unlikely that there were any operational factors that contributed to the accelerated formation of coking. The exact mechanism which resulted in the level of coking present in the B-sump could not be determined.

A CT7 engine failure or in-flight shutdown due to significant coking in the B-sump is a rare event, with only two known occurrences in the 38 million flight hours accumulated by the engine type.

Findings

These findings should not be read as apportioning blame or liability to any particular organisation or individual.

- Excessive coking in the B-sump oil cavity resulted in oil leaking from the B-sump. This ultimately initiated an internal engine fire and subsequent fracture of the PT shaft and separation of the C-Sump assembly.
- The excessive coking was most likely due to the component not being completely clean when installed at the last major workscope and/or accelerated coking on the component.

Safety action

Whether or not the ATSB identifies safety issues in the course of an investigation, relevant organisations may proactively initiate safety action in order to reduce their safety risk. The ATSB has been advised of the following proactive safety action in response to this occurrence.

Engine manufacturer

As a result of this occurrence, the engine manufacturers (GE) have advised the ATSB that they:

- have completed a technical review and incorporated changes to the Maintenance Manual troubleshooting procedure to better identify a B-sump flooding condition.
- are ensuring licensed CT7-TP overhaul facilities are conducting the cleaning in accordance with the GE procedure. GE have also completed a review of the B-Sump cleaning procedure and developed enhancements which will be added to the next revision of the document.

General details

Occurrence details

Date and time:	29 August 2019 – 2245 EST	
Occurrence category:	Incident	
Primary occurrence type:	Engine failure or malfunction	
Location:	28 km north-east of Merimbula Airport, New South Wales	
	Latitude: 36° 43.88' S	Longitude: 150° 7.28' E

Aircraft details

Manufacturer and model:	Saab 340B	
Registration:	VH-RXX	
Operator:	Regional Express Pty Ltd	
Serial number:	340B-209	
Type of operation:	Air Transport Low Capacity - Passenger	
Departure:	Moruya, New South Wales	
Destination:	Merimbula, New South Wales	
Persons on board:	Crew – 3	Passengers – 19
Injuries:	Crew – 0	Passengers – 0
Aircraft damage:	Minor	

About the ATSB

The ATSB is an independent Commonwealth Government statutory agency. The ATSB is governed by a Commission and is entirely separate from transport regulators, policy makers and service providers. The ATSB's function is to improve safety and public confidence in the aviation, marine and rail modes of transport through excellence in: independent investigation of transport accidents and other safety occurrences; safety data recording, analysis and research; fostering safety awareness, knowledge and action.

The ATSB is responsible for investigating accidents and other transport safety matters involving civil aviation, marine and rail operations in Australia that fall within the ATSB's jurisdiction, as well as participating in overseas investigations involving Australian registered aircraft and ships. A primary concern is the safety of commercial transport, with particular regard to operations involving the travelling public.

The ATSB performs its functions in accordance with the provisions of the *Transport Safety Investigation Act 2003* and Regulations and, where applicable, relevant international agreements.

Purpose of safety investigations

The object of a safety investigation is to identify and reduce safety-related risk. ATSB investigations determine and communicate the factors related to the transport safety matter being investigated.

It is not a function of the ATSB to apportion blame or determine liability. At the same time, an investigation report must include factual material of sufficient weight to support the analysis and findings. At all times the ATSB endeavours to balance the use of material that could imply adverse comment with the need to properly explain what happened, and why, in a fair and unbiased manner.

About this report

Decisions regarding whether to conduct an investigation, and the scope of an investigation, are based on many factors, including the level of safety benefit likely to be obtained from an investigation. For this occurrence, a limited-scope, fact-gathering investigation was conducted in order to produce a short summary report, and allow for greater industry awareness of potential safety issues and possible safety actions.