DUTCH
SAFETY BOARD

Loss of engine power after takeoff

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The Hague, April 2023

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The Dutch Safety Board

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N.B: This report is published in the English language, with a separate summary in the Dutch language. If there is a difference in interpretation between the Dutch and English version, the English text will prevail.

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SUMMARY

On the morning of 25 June 2021, the Cessna 208B with registration PH-FST was parked inside the hangar of a maintenance organisation. The organisation performed maintenance tasks on the aircraft on a regular basis. The maintenance organisation had scheduled to perform a maintenance task before the planned flights that day. When the aircraft was on ground with the engine off, erratic and high engine Exhaust Gas Temperature (EGT) readings were reported. The maintenance organisation suspected a faulty magnetic pick-up in the engine's propeller governor to be the cause of these erratic EGT readings. A mechanic under supervision of a licenced engineer was tasked to replace the magnetic pick-up. After removal of the old magnetic pick-up, the mechanic followed steps one through four of the maintenance manual to install the new magnetic pick-up. Steps five through eight, a system voltage test to check correct installation, were not noticed by the mechanic and as a result not carried out. After connecting the wiring and tightening the lock nut, the mechanic, together with the pilot, did a static engine test run and performed the Single Red Line (SRL) check to verify the system and EGT readings.

After the system was found to be functioning correctly, the mechanic left the aircraft and the pilot taxied to the skydive organisation's building to pick up parachutists. Following the boarding of seventeen parachutists, the pilot taxied to runway 26 and commenced the takeoff roll. Shortly after takeoff, without any warning, the engine lost power at approximately 400 feet above field level. The pilot made an emergency landing in a field whereby the aircraft sustained substantial damage to the fuselage, wings, landing gear and propeller. One parachutist suffered minor injuries.

As no apparent reason was found why the engine ceased operating, the engine was removed from the aircraft and transported to an engine shop in Denmark for further testing and disassembly. Investigation revealed that the engine's propeller governor was damaged. Inside the propeller governor the ball head assembly was found damaged and debris was found within the governor housing. Also, damage to the pick-up end of the magnetic pick-up was found.

The damage was caused by contact between the magnetic pick-up and rotating parts of the propeller governor (the toothed gear). Metal debris restricted the free movement of the ball head assembly in the governor housing, likely displacing the metering valve aft and allowing all oil to drain from the propeller dome and causing the propeller to continuously move to the feather position. This increasing pitch of the propeller led to an increasing power demand, which the engine could not deliver. This resulted in a power reduction that reinforced itself until the engine flamed out.

It was determined that prior to the accident flight most probably the magnetic pick-up was installed in the governor assembly in between two gear teeth of the rotating gear. This was not noticeable during the normal engine autostart and SRL check (systems which also use magnetic pick-up input). The design of the propeller governor toothed gear makes it possible to position the magnetic pick-up in between two teeth. The maintenance manual did not specifically mention or address this possibility.

On 30 December 2021, the Dutch Safety Board published a safety alert on its website in the form of a preliminary report to present initial findings and highlight the possibility of positioning the magnetic pick-up in between the teeth of the ball head gear.

During the investigation the Dutch Safety Board had been informed by the engine manufacturer that two safety actions had been taken. On 11 March 2022, the engine manufacturer issued a Service Information Letter, indicating that improper installation of the magnetic pick-up can result in contact damage between the pick-up and teeth of the governor assembly. On 29 July 2022, the engine manufacturer issued a revision of the engine maintenance manual regarding the procedure for replacement of the magnetic pick-up. The maintenance organisation has taken safety actions to improve planning of maintenance and prevent distraction of mechanics while performing maintenance tasks. Because of the corrective actions already taken, the Safety Board does not issue safety recommendations.

ABBREVIATIONS

AMSL	Above mean sea level
CPL(A)	Commercial Pilot Licence (Aeroplane)
EASA	European Union Aviation Safety Agency
EGT	Exhaust Gas Temperature
EHTE	International Airport Teuge
FAA	Federal Aviation Administration
FCU	Fuel Control Unit
IAS	Indicated Airspeed
ICAO	International Civil Aviation Organization
IR SE	Instrument rating Single engine
NTSB	National Transportation Safety Board
RPM	Revolutions Per Minute
SEP	Single Engine Piston
SET	Single Engine Turbine
SRL	Single Red Line
TTL	Torque/Temperature Limiting
VFR	Visual Flight Rules

GENERAL OVERVIEW

Identification number:	2021062
Classification:	Accident
Date, time of occurrence:	25 June 2021, 09.33 hours[1]
Location of occurrence:	West of International Airport Teuge (EHTE)
Operator:	Skydive Teuge
Registration:	PH-FST
Aircraft type:	Cessna 208B Supervan
Aircraft category:	Fixed wing, single engine turboprop
Engine type	Honeywell TPE331-12JR
Type of flight:	Parachute drop
Phase of operation:	Initial climb
Damage to aircraft:	Substantial
Flight crew:	One
Passengers:	Seventeen
Injuries:	One passenger minor
Light conditions:	Daylight

1 All times in this report are local times (UTC + 2 hours), unless otherwise specified.

1 INTRODUCTION

On 25 June 2021 at 09.32 hours, a Cessna 208B with a pilot and seventeen parachutists on board departed from International Airport Teuge (EHTE). During the initial climb, the aircraft suddenly lost engine power after which the pilot made an emergency landing in a field close to a motorway. The aircraft was substantially damaged and one parachutist suffered minor injuries.

In accordance with the international standards of the International Civil Aviation Organization (ICAO) Annex 13 on Aircraft Accident and Incident Investigation, the Dutch Safety Board on behalf of the State of Occurrence conducted the safety investigation. The Accredited Representative of the National Transportation Safety Board (NTSB) of the United States of America (State of Design, State of Manufacture) and its technical advisors participated in and provided information for the investigation. The Dutch Safety Board also gathered information from the pilot, the operator, the aircraft maintenance organisation, the aerodrome and the European Union Aviation Safety Agency (EASA).

The investigation into the accident focused on the technical aspects of the accident and answers the following question:

What caused the aircraft to lose engine power shortly after takeoff?

The conduct of the emergency landing and subsequent evacuation were not investigated.

Chapter 2 presents the relevant factual information. In Chapter 3 the analysis is presented. Chapter 4 summarizes the findings and conclusions. Chapter 5 describes the safety actions taken by the engine manufacturer following the accident.

2 FACTUAL INFORMATION

2.1 History of the flight

On the morning of 25 June 2021, the Cessna 208B with registration PH-FST was parked inside the hangar of a maintenance organisation. The organisation performed maintenance tasks on the aircraft on a regular basis. The maintenance organisation had scheduled to perform an open maintenance task before the planned flights that day. This task was the replacement of the magnetic pick-up[2] in the engine's propeller governor. An aircraft mechanic removed the old magnetic pick-up, inserted the new one, connected the wiring and tightened the lock nut. A licensed engineer, being the authorised certifying staff, signed off this task because he was convinced that he verified that the replacement was done correctly.

At 09.00 hours, the mechanic asked the pilot to perform an engine test run on the ground to verify the correct functioning of the magnetic pick-up. After the pilot had completed the preflight check, the aircraft was rolled outside of the hangar for a test run. The pilot started the engine using the autostart function. The mechanic was also on board the aircraft during the test run and checked the Exhaust Gas Temperature (EGT) indication and performed the Single Red Line (SRL) check, including the verification of the non-illumination of the SRL light on the dashboard. All was found to be functioning correctly.

After the successful test run, the pilot proceeded directly to the skydive organisation's building to pick up seventeen parachutists. The aircraft had been fuelled the day before and contained sufficient fuel for the flight. Following the boarding of the parachutists, the pilot taxied to runway 26 and commenced the takeoff roll with 20 degrees of flaps. Shortly after takeoff the pilot retracted the flaps and the aircraft continued to climb normally. At 09.33 hours, at an altitude of approximately 400 feet above field level[3], the engine suddenly lost power. The pilot stated afterwards that there were no aural and no visual warnings prior to the engine failure. According to the pilot, following the failure, the propeller moved to the feather position (uncommanded). Immediately, the pilot started looking for a suitable field for an emergency landing. As there was a motorway ahead, the pilot turned left in an attempt to stay away from the motorway and performed a flapless landing in a field.

2 The magnetic pick-up measures engine Revolutions Per Minute (RPM), see 2.5.2 for more details.
3 453 feet above mean sea level (AMSL). The elevation of International Airport Teuge is 17 feet AMSL.

After touchdown, the pilot steered to the left to avoid the motorway. He noted a ditch in the direction the aircraft was traveling. He attempted to pull up the nose of the aircraft and fly over the ditch, however the aircraft had slowed down to a speed whereby not enough lift could be produced. The nose gear collapsed after hitting the ditch and could not provide directional control anymore. After the right wing hit a billboard, the aircraft turned 180 degrees and came to rest in a small ditch against the crash barrier next to the motorway, see Figure 1.

Just before the emergency landing, the parachutists had opened the roll-up door in the back of the aircraft. After landing, the parachutists and the pilot left the aircraft using this exit. After evacuation, the pilot shortly returned to the cockpit to turn off the lights, avionics and battery.

Figure 1: The final position of the aircraft. (Source: Dutch Safety Board)

2.2 Injuries to persons

The injuries are depicted in Table 1. All passengers on board were parachutists. One parachutist received minor injuries.

Table 1. Overview of injuries

Injuries	Flight crew	Passengers	Total in the aircraft
Fatal	0	0	0
Serious	0	0	0
Minor	0	1	1
None	1	16	17
TOTAL	**1**	**17**	**18**

2.3 Damage to aircraft

The aircraft sustained substantial damage to the fuselage, wings, landing gear and propeller as a result of the emergency landing in the field and the collision with the billboard and ditch.

2.4 Personnel information

Pilot
The pilot, age 58, held a valid Commercial Pilot Licence - Aeroplane (CPL(A)) issued in the Netherlands with the following ratings: Instrument Rating Single Engine (IR SE), Single Engine Piston (SEP), Cessna 208B Single Engine Turbine (SET). The medical class 1 certificate was valid until 17 July 2021. The pilot stated that he had been flying the Cessna 208 since the year 2009. He had been flying for the skydive operator as part of a pilot pool since 2010.

The pilot's latest logbook showed 5,093 hours on single engine aircraft, of which 2,365 hours on single engine turbine aircraft. In addition, 1,022 hours on multi engine aircraft were recorded. The last flight prior to the accident flight was on 23 June 2021. During the previous seven days, the pilot had flown two hours on a single engine piston aircraft and four hours on a single engine turbine aircraft (Cessna 208B, owned by same skydive operator).

Maintenance personnel
The mechanic who replaced the magnetic pick-up was a graduated maintenance mechanic working under the supervision of a licensed engineer. The licensed engineer who supervised the mechanic and signed off the maintenance task, held a valid Part-66[4] aircraft maintenance licence A and B1 for aeroplanes (turbine and piston) and helicopters (turbine and piston). The licensed engineer had obtained his first Part-66 ratings in 2009 and his full B1.1 rating for single turbo-propeller engine aeroplanes in October 2014.

4 Part-66 is the Annex III to Regulation (EU) No 1321/2014 and contains requirements for aircraft maintenance certifying staff.

2.5 Aircraft and engine information

2.5.1 General information

The aircraft

Manufacturer	Cessna
Model	208B Supervan
Year of manufacture	2000
Serial number	208B0823
Registration	PH-FST
Maximum takeoff mass	4,110 kg

The Cessna 208B is a single engine turboprop high wing aeroplane. In 2017, for the purpose of enhanced performance, the standard engine was replaced with a Honeywell TPE331 engine, a Hartzell propeller and associated components, in accordance with Supplemental Type Certificate SA10841SC issued by the United States' Federal Aviation Administration (FAA). Following the engine replacement, the aircraft was exported to the Netherlands and registered as PH-FST. The aircraft had a valid Certificate of Airworthiness and Airworthiness Review Certificate.

The aircraft was used for skydiving operations. The aircraft operating time recorded by hobbs – a meter that measures the amount of time that an aircraft is in operation – was 9,251.1 hours, including the accident flight.

On 24 June 2021, the day before the accident, the aircraft had been refuelled with 320 litres of Jet A1. After refuelling, one flight was performed that same day. The accident flight was the first flight the next day.

The aircraft had a Garmin G600 avionics device mounted on the instrument panel. GPS position data was retrieved from this device, see paragraph 2.9.

The engine

Manufacturer	Honeywell
Model	TPE331-12JR
Date of service entry	March 2017
Serial number	P123211

The Honeywell TPE331-12JR is a constant speed engine with the compressor and turbine mounted on a common single shaft. The operating principle of the engine and description of relevant systems to this investigation are further described in the paragraphs below.

The engine was new when installed on the aircraft in March 2017. At the time of the accident it had run approximately 1,454 hours.

The last annual inspection was done by the maintenance organisation on 11 January 2021. Last maintenance on the aircraft before the accident was done on 27 May 2021 (unrelated to the present accident). The aircraft was not equipped with engine data recording devices.

2.5.2 Engine operating principle

The TPE331 is a single-shaft constant speed turboprop engine. The propeller is connected to the gas turbine by a fixed single shaft through a propeller gearbox. Within this constant speed principle there are two modes of operation: 1) Beta mode or ground range (between 68%-96% RPM[5]) and 2) propeller governing mode or flight range (between 96%-100% RPM). In de Beta mode (ground range), the engine/propeller speed is controlled by the fuel control unit (FCU) underspeed governor. In the propeller governing mode, constant engine/propeller speed is maintained by a propeller governor.

The flight crew controls the engine using two cockpit controls: the power lever and RPM lever (or speed lever). The power lever is used to control output power, the delivered power by the engine. The RPM lever is used to control the propeller governor RPM in both Beta mode and Propeller governing mode in their specific RPM ranges.

In the propeller governing mode - with the power lever in flight range - the power lever is controlling the manual fuel valve. Changing the power lever position, changes the fuel flow to the engine. This changes the engine RPM which changes propeller RPM. To maintain equilibrium between the commanded power lever setting and RPM setting (speed lever), the propeller governor makes minor changes to the propeller pitch (or propeller blade angle), thereby modulating its load to increase or decrease RPM. Increasing pitch decreases propeller RPM and decreasing pitch increases propeller RPM.

The engine of the accident aircraft was operating in the propeller governing mode when the loss of power occurred.

Description of relevant systems

Propeller governor

Propellers used on the TPE331 engine are spring loaded to the feather position and require oil pressure from the propeller control system to decrease propeller pitch. To change the pitch, the propeller control system meters oil to or from the propeller dome.

5 Revolutions Per Minute

The main components of the propeller control system are the propeller, the oil transfer tube (beta tube), propeller pitch control and the propeller governor.

The propeller governor is mounted at the rear of the gearbox. During the propeller governing mode of operation, the propeller governor meters the oil pressure to the propeller dome as a function of engine speed and power requirements. The metered oil flows into the propeller pitch control and through the oil transfer tube into the propeller dome and piston to control the propeller pitch.

The propeller governor assembly is composed of a sliding metering valve, speeder spring and a ball head assembly, which includes a toothed gear and flyweights, see Figure 2. When RPM changes, the flyweights, a component of the ball head assembly, change position and move the sliding metering valve. This leads to either releasing oil from or applying pressurised oil to the propeller dome, changing the propeller pitch and load.

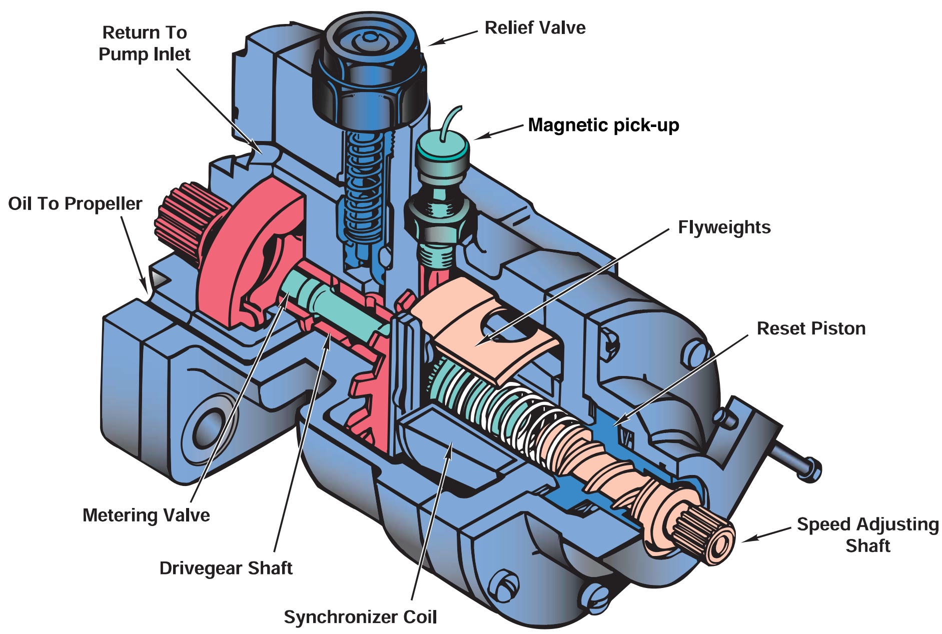


Figure 2: Simplified drawing of propeller governor. (Source: Honeywell TPE331 Line Maintenance Training Manual)

The governing mode has three operating ranges: under-speed, on-speed and over-speed:

- Under-speed: actual propeller RPM is less than the selected RPM. The propeller governor is applying oil pressure through the sliding metering valve to the propeller dome to reduce propeller pitch to increase RPM to resume to the on-speed condition;
- On-speed: balanced situation between actual and selected propeller RPM;
- Over-speed: actual propeller RPM is greater than selected RPM. The propeller governor is releasing oil pressure through the sliding metering valve from the propeller dome to increase propeller pitch to decrease propeller RPM to the on-speed condition.

RPM measuring
A speed sensing magnetic pick-up in the propeller governor assembly creates a magnetic field at the pick-up end (near the rotating toothed gear). When a metal tooth of the ball head gear passes through this field, it changes the magnetic field. This change in magnetic field creates a voltage change within the magnetic coil. The rate of these voltage changes is proportional to engine and propeller RPM. The speed signal is sent to the Single Red Line (SRL) controller and the Torque/Temperature Limiting (TTL) system.

The magnetic pick-up is a threaded part and installed in the propeller governor by turning the part in the assembly and tightening it with a locknut. The magnetic pole is in the centre of the sensor housing, see Figure 3a and 3b. The brazing material used for the core is silver.

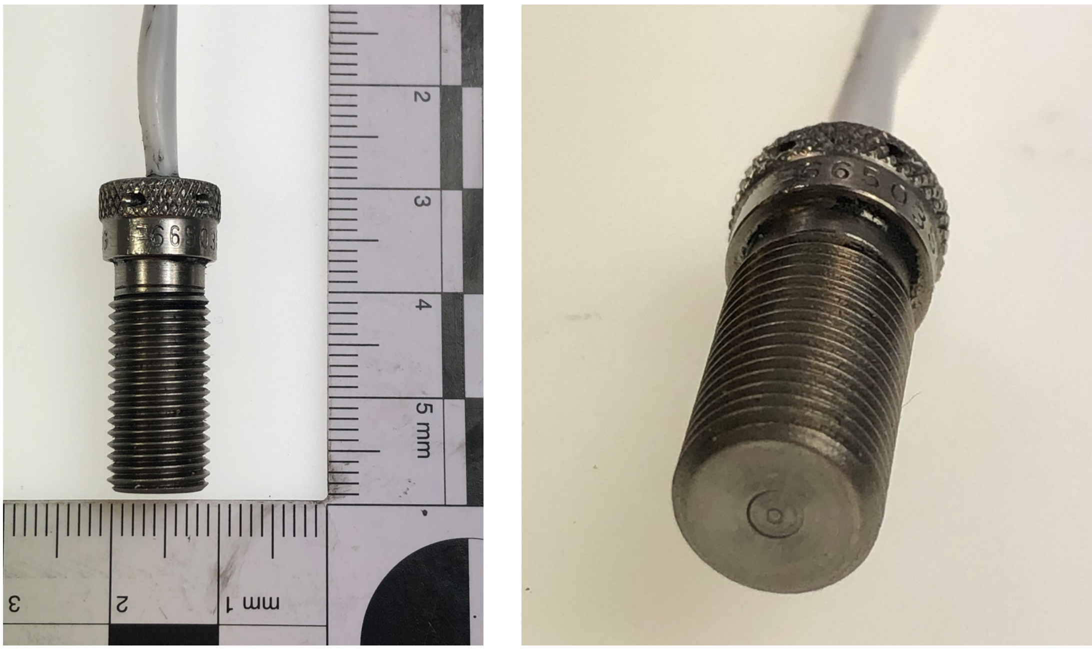


Figure 3a and 3b: Magnetic pick-up in its original state. (Source: Dutch Safety Board)

Single Red Line (SRL) controller
The SRL controller is an electronic control box designed to be used with the Exhaust Gas Temperature (EGT) measuring system. The SRL controller calculates a single EGT limit under various ambient and operational conditions which is presented on the EGT indicator in the cockpit. The SRL temperature conditioning system becomes functional above 80% RPM. This can be verified by performing the SRL check. The SRL controller receives the RPM speed signal from the propeller governor's magnetic pick-up.

Torque/Temperature Limiting (TTL) system
The TTL system is designed to automatically limit maximum torque or temperature. When either torque or temperature (input from SRL controller) reaches the set limit, a signal is transmitted to the torque limiter assembly which limits fuel flow to the engine.
The TTL system receives the RPM speed signal from the propeller governor's magnetic pick-up to maintain propeller speed stability during fuel limiter system operation.

Fuel Control Unit (FCU)
Fuel flows from the aircraft fuel system to the fuel pump assembly, and to the Fuel Control Unit, where fuel is metered to the engine for all operating conditions.

2.6 Meteorological information

The Royal Netherlands Meteorological Institute (in Dutch: *Koninklijk Nederlands Meteorologisch Instituut*) reported that at the time of the occurrence, the weather in the vicinity of International Airport Teuge was dry with good visibility (more than 10 kilometres), scattered clouds and locally broken cirrocumulus and stratocumulus (cloud base at 3,000 to 5,000 feet). The wind and temperature are depicted in Table 2.

Table 2: Wind and temperature around Teuge on 25 June 2021 between 09.30 and 10.00 hours. (Source: Royal Netherlands Meteorological Institute)

	Wind direction (degrees)	Wind speed (knots)	Temperature (°C)
Ground	190	5-7	16
At 500 feet	220	10-15	11

2.7 Aerodrome information

International Airport Teuge is an uncontrolled aerodrome with one asphalt runway (runway identification 08/26) with a length of 1,199 meters. The airspace classification is class G up to 1,500 feet above mean sea level (AMSL). The Visual Flight Rules (VFR) departure procedure for runway 26 is to climb to 717 feet AMSL (or 700 feet above field level) at the takeoff leg and to leave the circuit in northwesterly direction.[6]

The airport authority checked the aviation fuel daily for contamination. No abnormalities were found by the airport authority or reported by users on either 24 and 25 June 2021.

2.8 Wreckage and impact information

The track of the emergency landing in the field is shown in Figure 4. During the ground roll, the aircraft collided with a billboard with the right wing. The aircraft came to rest in a ditch.

The aircraft sustained impact damage resulting from the landing in the field, the collision with the billboard and contact with the ditch, see Figure 5. The flaps were found in an extended position between 0 and 10 degrees.

6 See Aeronautical Information Publication (AIP) the Netherlands. If the altitude of 717 ft AMSL (700 ft AAL) is not yet reached over the visual circuit Marker A, a climbing right hand turn is allowed.

The engine was intact and showed no signs of external damage, overheating or leakages. Also, no loose or disconnected fittings or lines were observed. The power lever, speed lever and the fuel lever in the cockpit were found in the maximum power and maximum speed position. The ignition switch on the start panel was in the AUTO position. At the accident site, all four propeller blades were found in a low pitch position against the start locks. Three blades were bent and damaged. Before removal of the wreckage, fuel was drained from both wing tanks.

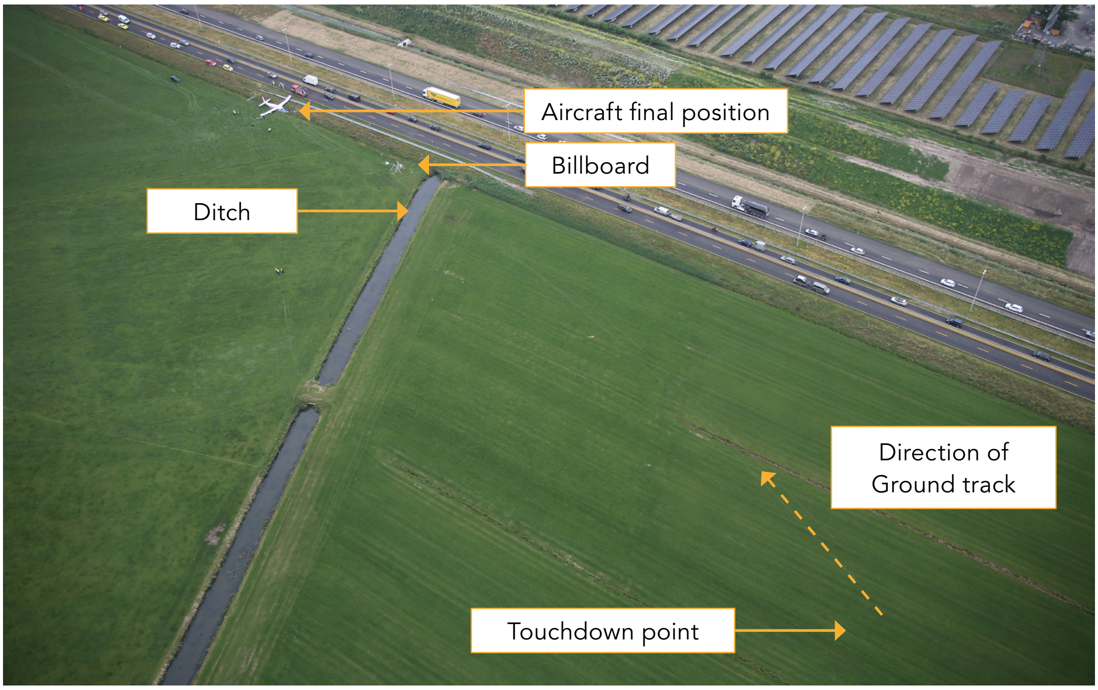


Figure 4: Ground track of the aircraft. (Source photo: Dutch Aviation Police)

Figure 5: The aircraft's final position. (Source: Dutch Safety Board)

2.9 Flight data

The aircraft was not equipped with a flight data recorder or engine data recording devices, but the aircraft had a Garmin G600 avionics device. GPS position data from the Garmin device indicated that the takeoff roll commenced around 09.32:10 hours and the aircraft got airborne shortly after. It is assumed that the engine failure occurred just before reaching the highest measured altitude of the flight. Based on the data, the time of the engine failure occurred at approximately 09.33:00 hours. The ground roll of the aircraft started around 09.33:33 hours. The aircraft came to rest in the ditch at 09.33:42. The aircraft reached a maximum altitude of 453 feet AMSL[7] and a maximum speed of 110 knots Indicated Airspeed (IAS) during its flight. See Appendix B for more details of selected flight data parameters.

In addition to the Garmin data, use was made of data extracted from AirFee, an automated movement registration system used by the aerodrome. AirFee data was collected for the accident flight and previous flights of PH-FST, during the seven days leading up to the accident. Figure 6 shows the pressure altitude (1013 mbar reference) of the aircraft during the accident flight in comparison to the mean altitude (climb) profile of previous flights. This data provides a rough indication of the climb profile of the accident flight.[8] The data shows that the climb profile of the first part of the flight (up to the point of the engine failure) coincides with the mean altitude profile of previous flights.

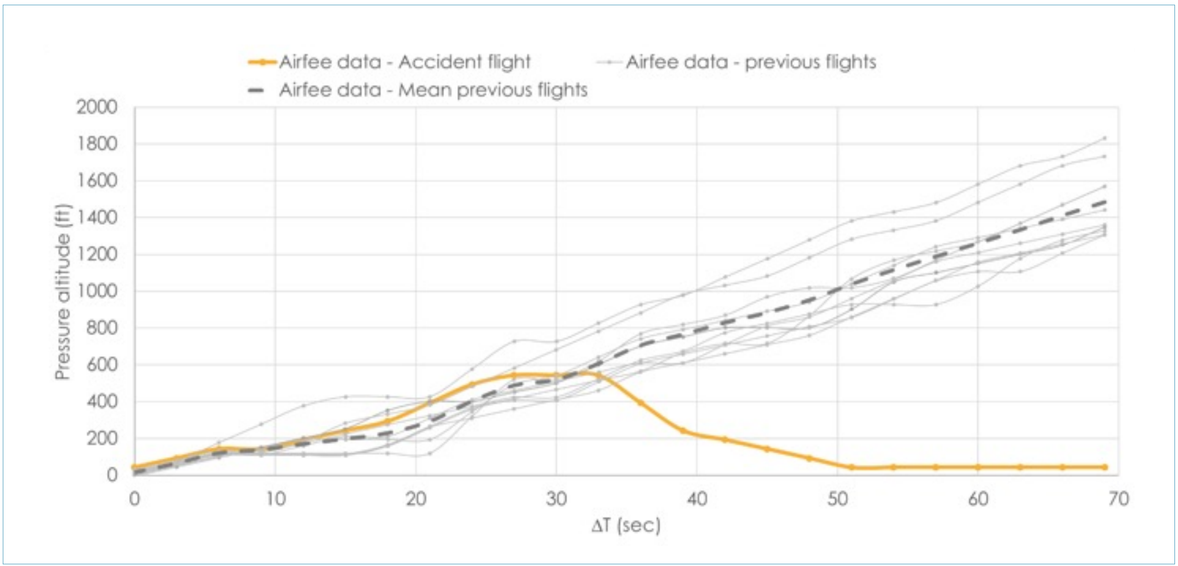


Figure 6: The pressure altitude of the aircraft during the accident flight as indicated by AirFee data compared to previous flights including the mean value as a reference.

7 Approximately 436 feet above field level.
8 In this comparison, aspects such as differences in aircraft weight and atmospheric conditions are not taken into account.

2.10 Tests and examinations

This paragraph summarizes the relevant findings of the technical examinations performed on the aircraft wreckage and engine. All tests and examinations were conducted by or under the supervision of Dutch Safety Board investigators, unless specifically indicated otherwise.

After the accident, the aircraft wreckage was moved to a hangar where initial tests and examinations were performed. The engine was removed from the aircraft and transported to an engine shop in Denmark for further testing and disassembly. The propeller governor, Fuel Control Unit, SRL controller and TTL system were further examined on the premises of the respective manufacturers.

2.10.1 General observations

This paragraph contains a summary of the general observations:
- Visual and borescope inspection of the engine air inlet, compressor, combustion chamber and turbine did not reveal any abnormalities.
- Control cable continuity from the cockpit to the engine controls for both power lever and speed lever was confirmed.
- Fuel was found in all fuel lines to the engine. No debris was found in the airframe and engine mounted fuel filters when visually inspected. The fuel shutoff valve was found in the open position.[9]
- The wiring of the magnetic pick-up of the propeller governor was found to be intact and connected correctly.
- The propeller blades did not show evidence of high-speed rotation at impact, see Figure 7. One blade appeared undamaged. The orientation of the damage on the blades was mostly spanwise, see Figure 8. No significant damage was found on the leading edges of the blades. All four blades were found in the start lock position.[10] Some deformation was noted in the different blade attachments assemblies and for one blade, the start lock pin and start lock plate did not touch.

9 The purpose of the fuel shutoff valve is to introduce fuel to the engine during engine starting and to shutoff fuel when the stop switch is actuated.

10 The Hartzell propeller has a start lock mounted at the base of each blade. The start lock consists of a spring loaded pin and a start lock plate. When the start lock is engaged, it holds the propeller blades at or near a flat pitch (zero degree) during ground starting of the engine (Source: Honeywell TPE training Guide).

Figure 7: Propeller blade damage. (Source: Dutch Safety Board)

Figure 8: Spanwise damage on prop blade. (Source: Dutch Safety Board)

2.10.2 Propeller governor

The engine was put on a test stand. The engine started without any difficulties and operated for a brief period of time at idle with the propeller against the start locks. After approximately two minutes at idle speed, the magnetic chip detector detected metal debris in the engine oil causing the magnetic chip detector light to illuminate. The engine was manually shutdown.

The engine was partly disassembled to identify the source of the metal debris. The propeller governor was removed from the engine and examined in more detail. The exterior of the propeller governor housing showed damage, see Figure 9. Also, damage to the pick-up end of the magnetic pick-up was noted, see Figure 10.

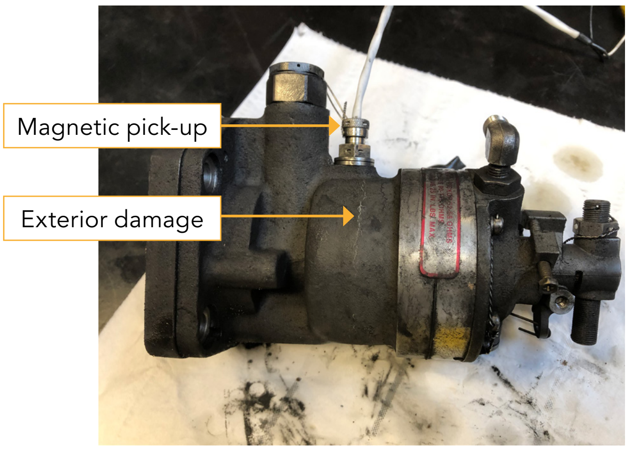


Figure 9: Damaged propeller governor. (Source: Dutch Safety Board)

Figure 10: Damaged magnetic pick-up. (Source: Dutch Safety Board)

The ball head assembly was found damaged and debris was found within the governor housing, see Figure 11. The ball head assembly showed several signs of damage. All teeth were missing from the ball head, except one tooth which was originally brazed to the ball head, see Figure 13 and Figure 14. The flyweight pins had slid out of the ball head and contacted the housing, causing scoring on the inside of the housing wall, see Figure 15. The damage on the outside of the propeller governor housing consisted of a circumferential crack coinciding with the location of the flyweight pins inside the housing.

At the bottom of the housing, some particles were embedded into the housing, see Figure 16. Some particles had a scoring trail behind them; marks consistent with particles being between the housing and the ball head assembly during rotation. All debris found in the housing was collected. The larger loose pieces were identified as parts of teeth and the flyweight pin retainers (spring clips).

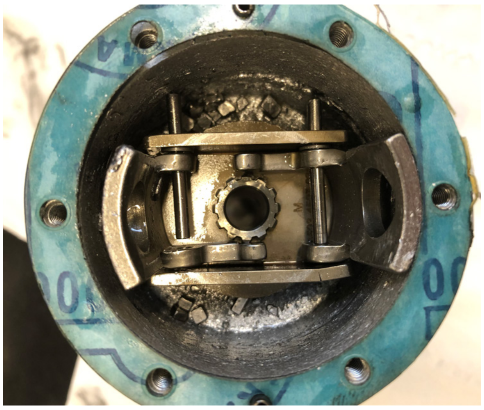


Figure 11: Debris found inside the governor housing. (Source: Dutch Safety Board)

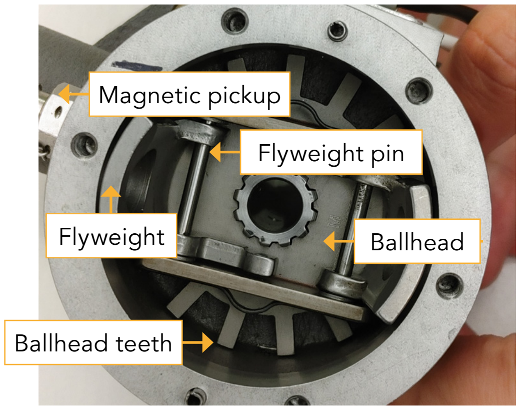


Figure 12: Picture of an undamaged governor. (Source: Woodward)

Figure 13: Bottom view of damaged ballhead assembly. (Source: Woodward)

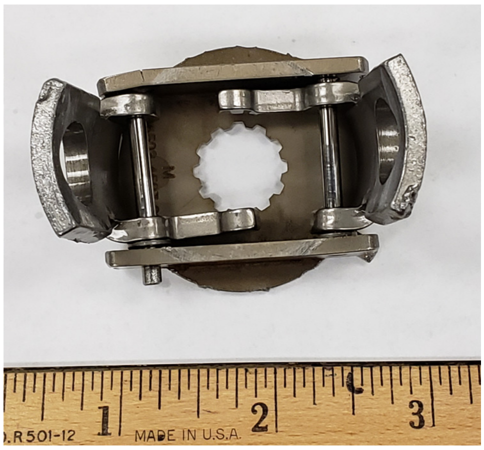


Figure 14: Top view of damaged ballhead assembly. (Source: Woodward)

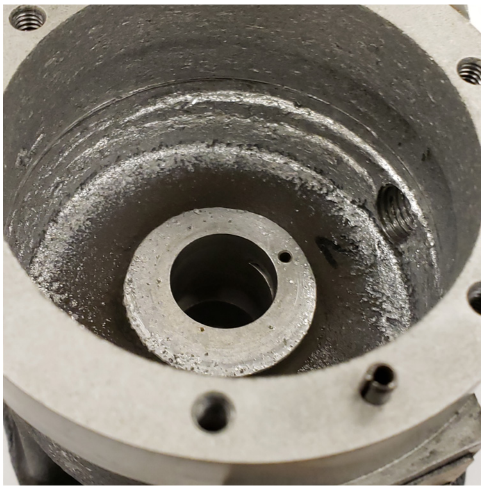


Figure 15: Scoring marks found inside the housing. (Source: Woodward)

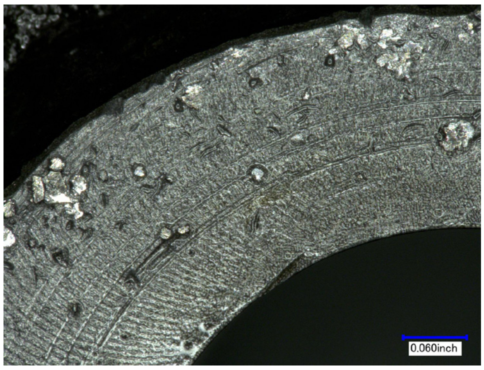


Figure 16: Particles embedded in bottom of housing. (Source: Woodward)

Further metallurgic examination performed by the propeller governor manufacturer concluded that the ball head gear teeth had fractured at the root. The initial failure mode was determined to be overload resulting from impact events consistent with rotation contact with the magnetic pick-up. The debris found inside the governor was consistent with governor component material, except for a small copper fragment that contained zinc and silver.

The remaining hardware of the governor was also examined for anomalies and operational condition. Both the pilot metering valve and the pressure relieve valve showed no abnormalities and all moved freely.

2.10.3 Examination of additional systems

The Torque/Temperature Limiting (TTL) system and Single Red Line (SRL) controller were found to be functional when tested at the facilities of the engine manufacturer.

The Fuel Control Unit was functionally tested at the facilities of the component manufacturer and no malfunctions were found.

2.11 Additional information

2.11.1 Installation of pick-up

Before the accident flight, the maintenance organisation[11] performed an open maintenance task: the replacement of the magnetic pick-up in the engine's propeller governor.

The replacement of the magnetic pick-up was done following an operator complaint that the EGT indicator showed an abnormally high temperature after engine shutdown and that it took a long time before the temperature was low enough to start the engine again. The maintenance organisation started troubleshooting and discovered that when switching the SRL controller off, as the SRL controller gets its RPM information from the magnetic pick-up, the temperature changed to within a normal temperature range. With the magnetic pick-up disconnected, the system appeared to work normally. Based on this information, the maintenance organisation concluded that the EGT reading was influenced by the SRL controller through a faulty magnetic pick-up. The maintenance organisation determined that the magnetic pick-up needed to be replaced. A new magnetic pick-up was ordered. Following receipt of the new pick-up, the replacement was done on 25 June 2021.

On this engine, the magnetic pick-up is located on the underside of the propeller governor, see Figure 17.

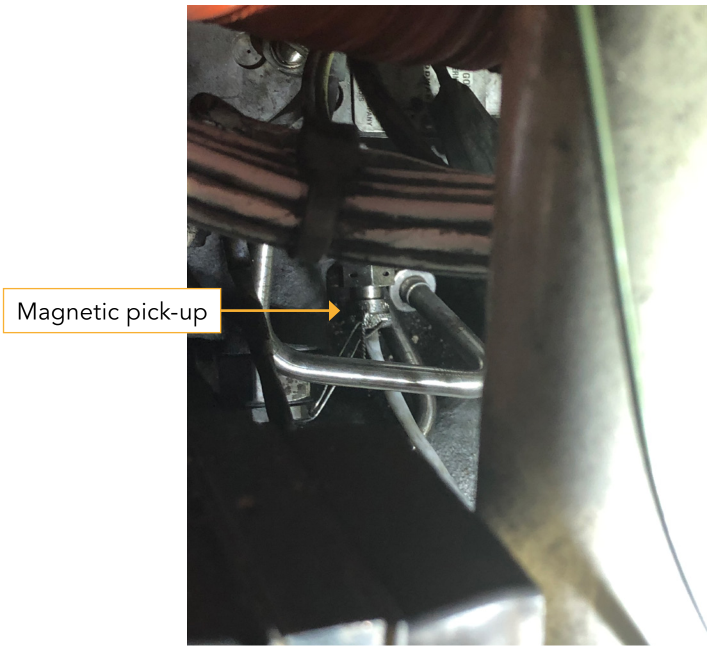


Figure 17: Location of magnetic pick-up in the engine. (Source: Dutch Safety Board)

11 The maintenance organisation involved was an approved Part-145 organisation. Part-145 contains the requirements to be met by an organisation to qualify for the issue or continuation of an approval certificate for the maintenance of aircraft and components (Regulation (EU) No 1321/2014). The replacement of the magnetic pick-up was a maintenance task performed under Part-145.

According to the maintenance manual part 72-10-03[12], the following steps need to be taken when installing the pick-up:

1. Install locknut and packing on new pick-up;
2. Install assembled pick-up in propeller governor assembly;
3. Turn pick-up in until it contacts flyweight head;
4. Loosen pick-up ½ turn and tighten locknut to a torque value of 22 to 25 inch-pounds;
5. Operate engine at 100% with no load and with voltmeter voltage. Voltage shall read 4.5 +- 0.5 volts peak-to-peak;
6. If 4 volts minimum cannot be met, loosen locknut and turn pick-up in (clock-wise) to increase voltage output;
7. After each adjustment, tighten locknut to a torque value of 22 to 25 inch-pounds;
8. Install clamp, washer and screw. Tighten screw to a torque value of 18 to 22 inch-pounds.

The manual contains a caution message after step five: 'Do not position the magnetic pick-up closer than one eighth turn from flyweight head'.

In the maintenance manual, the procedure is divided into three pages, see Appendix C. Steps one to four are listed on the first page. Page two contains a drawing (partial breakdown) of the propeller governor assembly and magnetic pick-up. Steps five to eight on the check of the voltage output are listed on the third page of the procedure. This check serves to verify the correct functioning of the magnetic pick-up.

The mechanic stated to have followed all the required steps in the maintenance manual. The mechanic was under the impression that step four was the last step of the procedure and was not aware of steps five, six, seven and eight on page three. The licensed engineer signed off the task after verification that the installation was done, but he did not detect that procedure steps five to eight were not completed. The maintenance personnel involved stated they experienced pressure to complete the task timely.

On ground, before the aircraft was released to service, the system check for the SRL controller was performed in accordance with the Supervan Systems' Airplane Flight Manual Supplement and the system was found serviceable.

2.11.2 Previous occurrences

The databases of the engine manufacturer did not show occurrences where the magnetic pick-up was damaged and/or the teeth of the ball head assembly were damaged or broken. The database of the propeller governor manufacturer contained six reports (dated years 1993, 1995, 1999, 2004 (two reports) and 2005) of a damaged magnetic pick-up and/or internal damage to the governor ball head assembly.

One occurrence was found in the Federal Aviation Administration's Service Difficulty Report database. The report dated from 2004 and states that the ball head assembly was missing all its teeth, caused by contact with the magnetic pick-up during rotation of

12 Honeywell Maintenance Manual TPE331-12, pages 205 and 206 dated Dec 8/08 and page 207 dated Sep 17/03.

the ball head. The magnetic pick-up had recently been replaced as a fault finding action for EGT fluctuations.

None of the occurrence reports retrieved contained details on the consequences of the damage in the propeller governor or of the magnetic pick-up. In none of the reports reference is made to a loss of engine power.

2.11.3 Publication of safety alert
On 30 December 2021, the Dutch Safety Board published a safety alert on its website in the form of a preliminary report to present initial findings and highlight the possibility to position the pick-up end of the magnetic pick-up in between the teeth of the ball head gear, see Figure 18. During the investigation the possibility to position the pick-up end of the monopole in between the teeth of the toothed gear was demonstrated. In such case, it was determined that loosening it by a half turn, as required by the maintenance instructions, is insufficient to ensure free rotation of the toothed gear.

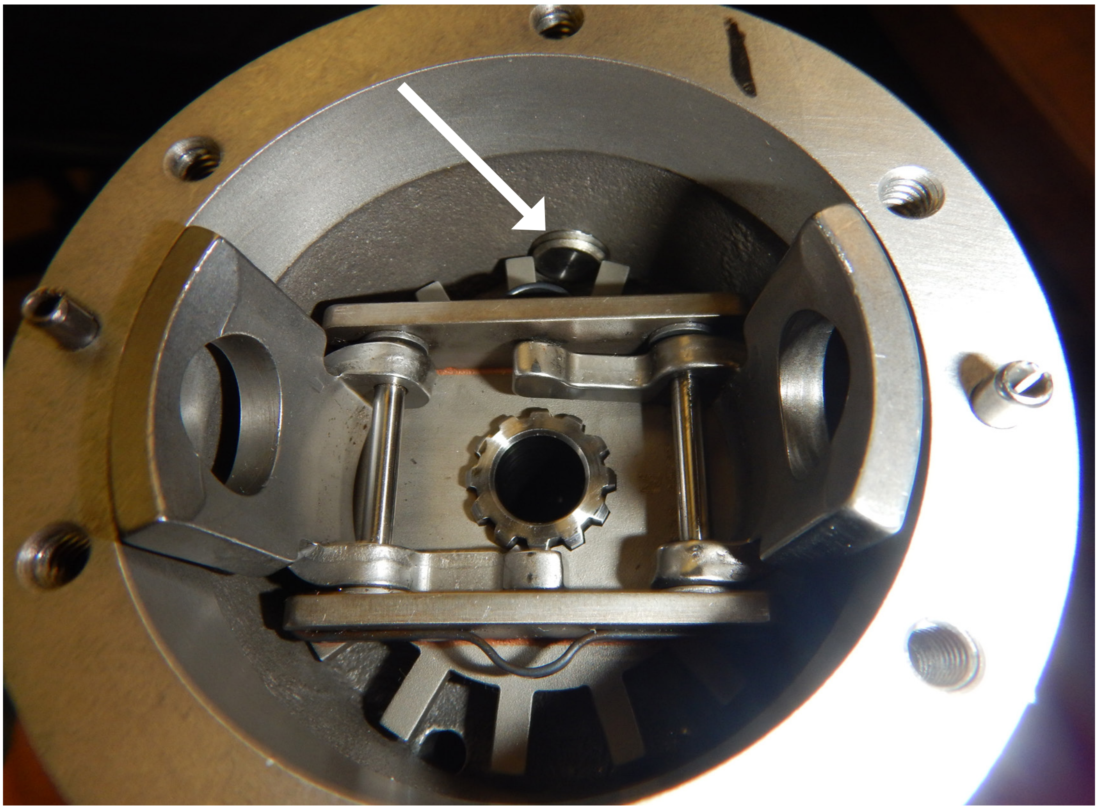


Figure 18: An undamaged toothed gear with magnetic pick-up positioned in between teeth, see arrow. (Source photo: Honeywell Aerospace)

2.11.4 Design of the toothed gear
The first TPE331 engine was designed in 1959 and certified by the United States' Federal Aviation Administration (FAA) in 1965. Over the years new models were introduced with higher horsepower ratings. The propeller governor used in TPE331 engines uses either a 15 or 29 toothed gear, depending on the design requirements.

Engines equipped with an electronic fuel control and propeller governor with a servo actuator incorporate a 29 toothed gear. The 15 toothed gear version is used in engines that utilize a hydro mechanical fuel control, including the TPE331-12JR engine model installed in the accident aircraft. Both propeller governor types use the same magnetic pick-up. As the distance between two teeth of the 29 toothed gear is smaller, it is not possible to position the magnetic pick-up in between two teeth of this version.

According to the engine manufacturer, approximately 7,778 TPE engines have been produced with propeller governors using the 15 toothed gear. At least around 2,700 engines were still operational during May 2022.[13]

13 The engine manufacturer does not have a full overview of the number of TPE engines that are operational today. The estimate provided here is considered to be conservative and based on the number of engines for which oil analysis samples were submitted to laboratories approved by the engine manufacturer and is therefore only indicative of the number of engines operational.

3 ANALYSIS

3.1 General

The pilot was licensed and current on aircraft type (Cessna 208B). With visibility of more than 10 kilometres, clouds scattered at 3,000 to 5,000 feet and a light crosswind during takeoff, the weather is not considered to be a factor in the accident.

The fuel purge system was found pressurized and the fuel shutoff valve in the open position. This indicates that the stop-and-feather handle and fuel switch most probably remained on, not interrupting fuel supply. Fuel was found in all lines throughout the engine. During the investigation, no abnormalities were found in the Fuel Control Unit (FCU) or fuel pumps. No evidence of a malfunction in the fuel system was found.

After the accident, the propeller blades were found in the start lock position. The damage to the propeller blades, with different amounts of bending and the absence of damage to one blade, indicate that there was little or no rotation at the time the propeller impacted the ground. It is considered feasible that, as there was little rotation, ground contact by one or more blades forcefully rotated the blades against the start locks. The deformation of one of the blade attachments where the start lock pin and start lock plate did not touch, is an indication of impact force on the propeller.

3.2 Loss of engine power

The damage observed on the toothed gear and the magnetic pick-up, indicated rotational contact of the teeth with the magnetic pick-up. It has been determined that most probably the magnetic pick-up had turned in the governor assembly slightly in between two gear teeth. This was not noticeable during the normal engine autostart and SRL check (systems which also use magnetic pick-up input). This resulted in damage to the magnetic pick-up, the ball head assembly and the propeller governor housing.

Two consequences of the propeller governor damage and their contribution to the loss of engine power were investigated:

- the inability of the damaged magnetic pick-up to transmit a correct signal;
- physical damage of the propeller governor.

Damaged magnetic pick-up

The two systems that are directly affected by a loss of signal of the magnetic pick-up are the Single Red Line (SRL) controller and the Torque/Temperature Limiting (TTL) system. The TTL system is also indirectly affected through the SRL controller. When the signal to the SRL controller is lost or distorted, the monitor function of the SRL controller will detect the distorted signal and activate an SRL inoperative caption light in the cockpit to inform the pilot that the SRL controller is inoperative. The TTL system uses the direct (RPM) signal to prevent speed hunting when the TTL varies fuel flow. It uses the indirect signal from the SRL controller for temperature information for temperature limiting.

It is not considered likely, however, that the loss of signal to the SRL controller and TTL system resulted in a complete loss of engine power. The SRL controller has no direct fuel limiting authority and the TTL limiter can only bypass a limited amount of fuel.[14]

Physical damage of the propeller governor
Scoring marks and embedded debris in the propeller governor housing indicated that debris entered between the ball head assembly and the housing. It is plausible that during operation of the governor with a damaged ball head and damaged magnetic pick-up, one or more larger debris particles temporarily became lodged between the ball head and the housing and shifted the sliding metering valve, draining oil from the propeller dome. Draining oil from the propeller dome increased propeller pitch, increasing load and reducing propeller RPM. Because of the continuing release of oil pressure and under influence of the propeller counter weights and the feather spring in the propeller hub, the propeller pitch increased and moved towards the feather position. A detailed schematic of the propeller control system is provided in Appendix D.

As the TPE331 engine is a single shaft engine, propeller RPM is directly related to engine RPM. Engine RPM is directly related to the compressor discharge (P3) pressure, which is an input for the Fuel Control Unit (FCU). When engine RPM decreases, P3 pressure also decreases. Through a mechanical three-dimensional cam and lever within the FCU, P3 pressure positions the metering valve to meter fuel flow to the engine. As P3 drops, the fuel flow to the engine is reduced. Fuel flow will continue to decrease with decreasing RPM and subsequent P3 pressure until the engine flames out. In short, the increasing pitch of the propeller led to an increased power demand, which the engine could not deliver. This resulted in a power reduction that reinforced itself. The propeller continued to move to the feather position and eventually ceased rotation. This scenario is in line with findings from the technical investigation, during which no evidence was found of engine over-torque or engine over-temperature conditions.

The extent to which the sliding metering valve was displaced, affected the rate at which the propeller feathered. The exact displacement of the pilot metering valve could not be determined. According to the manufacturer of the propeller governor, the release of oil from the propeller dome through the opening of the pilot metering valve will allow more than enough flow to lower the propeller oil pressure a significant amount. It is likely that during the accident sequence, the feathering of the propeller and the engine shutdown occurred in short succession or nearly simultaneously.

14 According to the engine manufacturer, the TTL system can limit fuel up to 125 +/-5 pph total. For reference, an engine at takeoff power will be consuming approximately 500-600 pph.

3.3 Maintenance aspects

The replacement of the magnetic pick-up is a delicate task. The steps of the prescribed procedure must be carefully followed which according to the maintenance organisation is difficult, due to the small working space (difficult to hold sensor in place and torque the lock nut). The engineers stated that they experienced pressure to complete the difficult task timely. Maintenance staff must verify that all steps of the procedure have been completed. The procedure assumes that when installing the magnetic pick-up, the pick-up contacts the tooth end of the gear followed by loosening the pick-up by half a turn, thereby creating a small calibrated space between the pick-up end and the toothed gear. The procedure did not prescribe to verify the position of the teeth before installing the magnetic pick-up.

With the 15 toothed gear, there is a possibility to position the pick-up end in between two teeth. In such a case, the pick-up is installed deeper than when placed correctly. Loosening the magnetic pick-up half a turn is insufficient to ensure necessary clearance between the pick-up end and the gear and the pick-up contacts the toothed gear when the gear starts to rotate.

It is possible that the voltage check could have shown that the measured value did not correspond with the value mentioned in the procedure. However, steps five to eight of the procedure, which included the voltage check, were not performed. There was no specific reference made in the manual that the procedure for the installation of the pick-up continued on page three, after the drawing on page two. The procedure also did not include an alert to the possibility of incorrectly positioning the toothed gear.

Both the design of the toothed gear and the procedure in the maintenance manual allowed for the incorrect installation of the pick-up.

4 CONCLUSIONS

During the initial climb after takeoff, the aircraft suffered a complete loss of engine power as a result of the uncommanded feathering of the propeller. This feathering was the result of damage that occurred within the propeller governor. Most probably, the incorrect installation of the magnetic pick-up in the propeller governor prior to the accident flight led to contact damage between the pick-up and the rotating toothed gear. Debris restricted the free movement of the ball head assembly in the governor housing, allowing all oil to drain from the propeller dome and causing the propeller to continuously move to the feather position and eventually cease rotation. The increasing pitch of the propeller led to a power reduction of the engine which reinforced itself. The distorted output signal of the damaged magnetic pick-up did not cause the engine flame out.

The design of the propeller governor's toothed gear makes it possible to position the magnetic pick-up in between its teeth. The maintenance procedure for the replacement of the magnetic pick-up did not specifically mention or address this. The final steps of this procedure, a voltage check to verify the correct placement of the pick-up, were not performed by the maintenance staff. The design of the toothed gear in combination with the procedure in the maintenance manual allowed for the incorrect installation.

5 SAFETY ACTIONS

According to the engine and component manufacturer, the sequence of events leading to this engine failure is unique. A search in different occurrence databases did come up with few cases of damaged magnetic pick-ups, but none of these occurrences appeared to have resulted in engine failure or complete loss of engine power. During the investigation, the engine manufacturer informed the Dutch Safety Board of two safety actions that were taken.

On 11 March 2022, the engine manufacturer issued a Service Information Letter[15] regarding the installation of the magnetic pick-up. The purpose of a Service Information Letter is to inform all affected operators and organisations of the issue mentioned in the letter and of the engine manufacturer's actions or proposed solutions. The letter indicated that improper installation of the magnetic pick-up can result in contact damage between the pick-up and teeth of the governor assembly and that this can result in loss of engine speed control signal and propeller governor functional control. The letter included images to show incorrect and correct positioning of the gear teeth when replacing the magnetic pick-up. A Service information Letter is not an integral part of the maintenance manual.

On 29 July 2022, the engine manufacturer issued a revision[16] of the engine maintenance manual regarding the procedure for replacement of the magnetic pick-up. The revision included:

- a warning statement regarding the possibility of incorrect placement of the magnetic pick-up resulting in severe damage to the propeller governor assembly;
- figures demonstrating how to ensure a tooth is centered within the magnetic pick-up port;
- more detailed instructions for ensuring the voltage is between 4-5 volts after magnetic pick-up installation/adjustments.

With the update of the maintenance manual, the engine manufacturer has taken action to prevent incorrect installation of the magnetic pick-up.

The maintenance organisation has taken safety actions to improve planning of maintenance and prevent distraction of mechanics while performing maintenance tasks.

Because of the corrective actions already taken, the Safety Board does not issue safety recommendations.

15 Publication Number D202203002272, updated on 17 May 2022 to Revision 1.
16 Temporary Revision No. 72-54.

APPENDIX A

RESPONSES TO THE DRAFT REPORT

In accordance with the Dutch Safety Board Act, a draft version of this report was submitted to the parties involved for review. The following parties have been requested to check the report for any factual inaccuracies and ambiguities:

- National Transportation Safety Board (NTSB)
- Honeywell Aerospace
- Texas Turbine Conversions
- Woodward
- Hartzell Propeller
- Skydive Teuge
- AMN
- Pilot
- Dutch Ministry of Infrastructure and Water Management
- European Union Aviation Safety Agency (EASA)

The responses received, as well as the way in which they were processed, are set out in a table that can be found on the Dutch Safety Board's website (www.safetyboard.nl).

The responses received can be divided into the following two categories:

- Corrections and factual inaccuracies, additional details and editorial comments that were taken over by the Dutch Safety Board (insofar as correct and relevant). The relevant passages were amended in the final report.
- Responses that were not adopted by the Dutch Safety Board. The reason for this decision is explained in the table.

APPENDIX B

FLIGHT DATA

The memory card of the Garmin G600 avionics device in the aircraft was retrieved and contained data logs of the accident flight and previous flights. The parameters that were recorded on the device included, amongst others, the device time, GPS position data (longitude, latitude), altitude and barometric settings, outside air temperature, indicated airspeed (IAS), ground speed, linear accelerations (lateral and normal) and aircraft attitude (roll and pitch). A selection of parameters are depicted in Figure 19.

Differences in the altitude as recorded by the Garmin device and by Airfee, see Figure 6 in the report, exist due to different altitude reference and measurement methods.

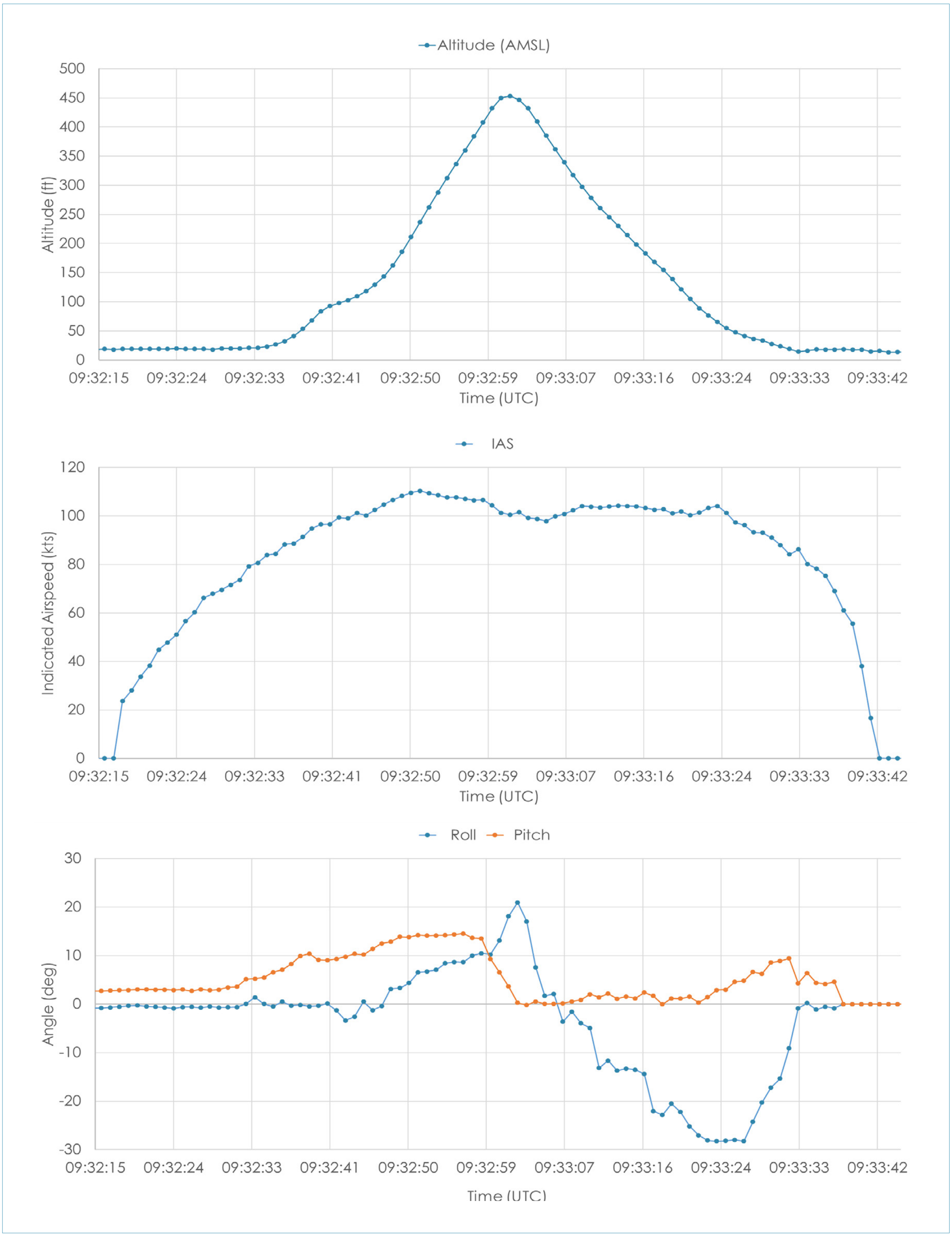


Figure 19: The altitude and speed profile and roll and pitch attitude of the aircraft during the accident flight, based on data from the Garmin G600 device.

MAINTENANCE PROCEDURE REPLACEMENT OF MAGNETIC PICK-UP

4. Approved Repairs

NOTE: *Table 202* provides a list of all equipment and materials required to perform Approved Repairs.

Table 202. Equipment and Materials

Equipment or Material	Manufacturer
NOTE: Equivalent substitutes may be used for listed items.	
Lubricant (Santovac OS-124 or Santovac 5)	CAGE: 1DDL9
Oil (Approved engine oil)	Commercially available
Propeller governor shaft packing (Part No. 1355-262)	Woodward Governor Co, 5001 N Second St, Rockford, IL 61101
Solvent (MIL-PRF-680)	Commercially available
Voltmeter (0 to 40 vdc ±5%)	Commercially available

A. Remove Magnetic Pickup *(See Figure 202)*

(1) Remove screw (5), washer (10), and clamp (15) securing lead to propeller governor.

(2) Loosen locknut (20) on pickup (25). Remove pickup, packing (30) and locknut.

(3) Remove packing and locknut from pickup. Discard packing.

B. Install Magnetic Pickup *(See Figure 202)*

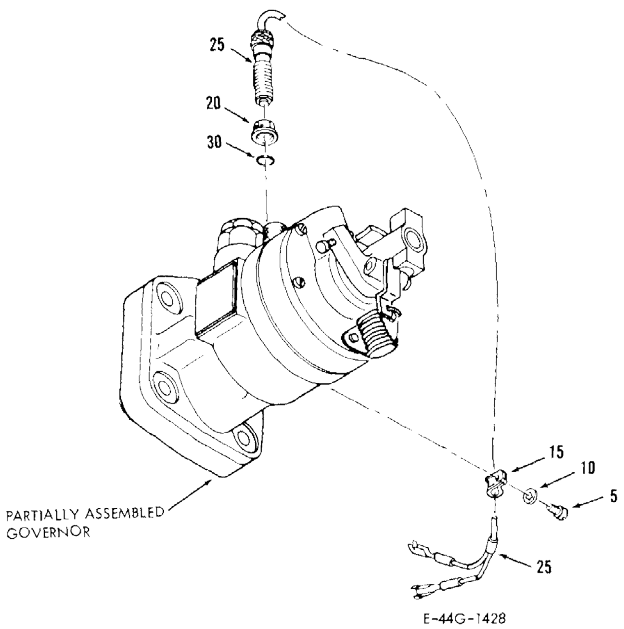
NOTE: Lightly coat new packings with clean engine oil or lubricant (Santovac OS-124 or Santovac 5).

(1) Install locknut (20) and packing (30) on new pickup (25).

(2) Install assembled pickup in propeller governor assembly.

(3) Turn pickup in until it contacts flyweight head.

(4) Loosen pickup 1/2 turn and tighten locknut (20) to a torque value of 22 to 25 inch-pounds.



5. SCREW (IPC, 72-10-03, *FIGURE 2)*
10. WASHER
15. CLAMP
20. LOCKNUT
25. MAGNETIC PICKUP
30. PACKING

Propeller Governor Assembly (Speed Signal Monopole) (Partial Breakdown)
Figure 202

UP783647

NOTE: A voltmeter can be used in place of an oscilloscope to check propeller governor voltage.

If voltmeter indicates (volts) peak-to-peak, no correction of reading is required.

If voltmeter indicates (volts) RMS, the voltmeter reading must be multiplied by 2.82885 to obtain corrected peak-to-peak reading.

4. B. (5) Operate engine at 100% with no load and with voltmeter check voltage. Voltage shall read 4.5 ±0.5 volts peak-to-peak.

CAUTION: DO NOT POSITION MAGNETIC PICKUP CLOSER THAN ONE EIGHTH TURN FROM FLYWEIGHT HEAD.

(6) If 4 volts minimum cannot be met, loosen locknut (20) and turn pickup (25) in (clockwise) to increase voltage output.

(7) After each adjustment, tighten locknut (20) to a torque value of 22 to 25 inch-pounds.

(8) Install clamp (15), washer (10), and screw (5). Tighten screw to a torque value of 18 to 22 inch-pounds.

C. Replace Propeller Governor Shaft Packing

(1) Remove propeller governor return spring, if required.

(2) Loosen arm on shaft and carefully slide arm approximately half way off shaft. Do not remove arm at this time.

(3) Place a reference mark on the shaft and propeller governor housing at the split line of arm to ensure proper positioning of arm when reinstalled.

(4) Remove propeller governor arm from shaft.

(5) Rotate shaft CCW until packing is exposed. Remove packing using a dental pick or equivalent tool.

(6) Clean the propeller governor spline shaft packing bore with solvent (MIL-PRF-680). Use low pressure air to dry part.

SCHEMATICS OF PROPELLER CONTROL SYSTEM

Figure 20 below illustrates the oil flow path during propeller governing mode at takeoff. Figure 21 illustrates the oil flow path with the displaced ballhead assembly and pilot metering valve. [Source: Honeywell Aerospace]

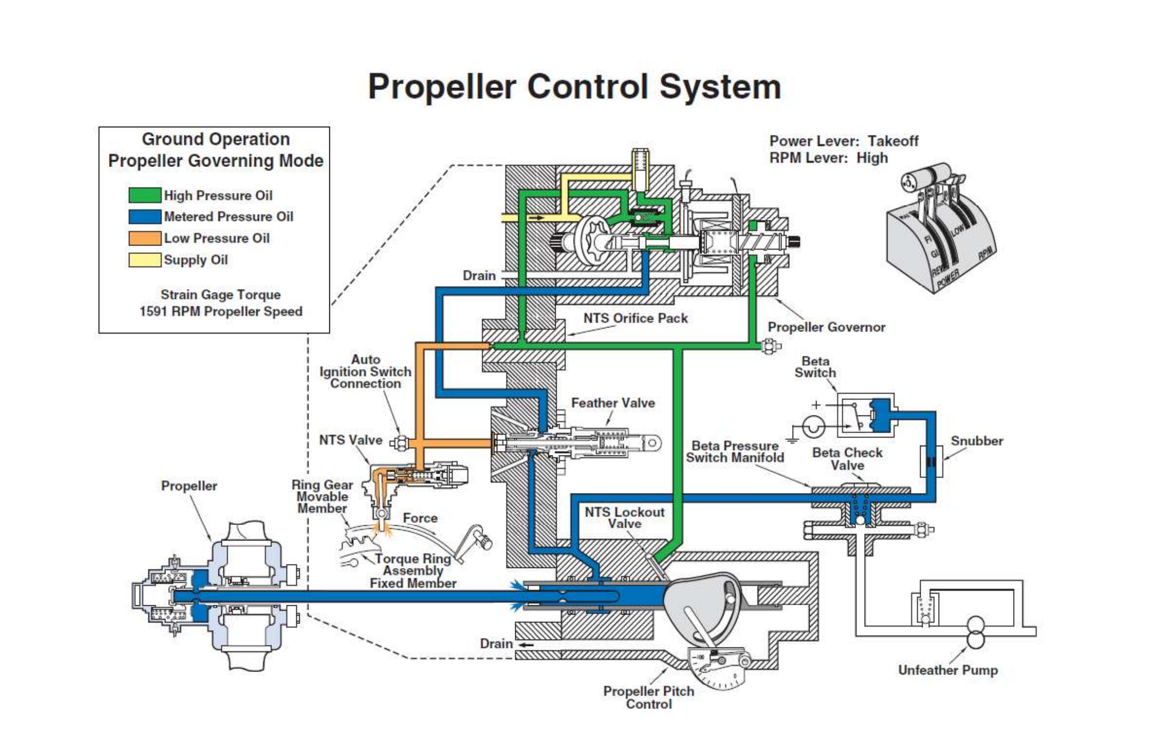


Figure 20: Propeller governing mode at Takeoff.

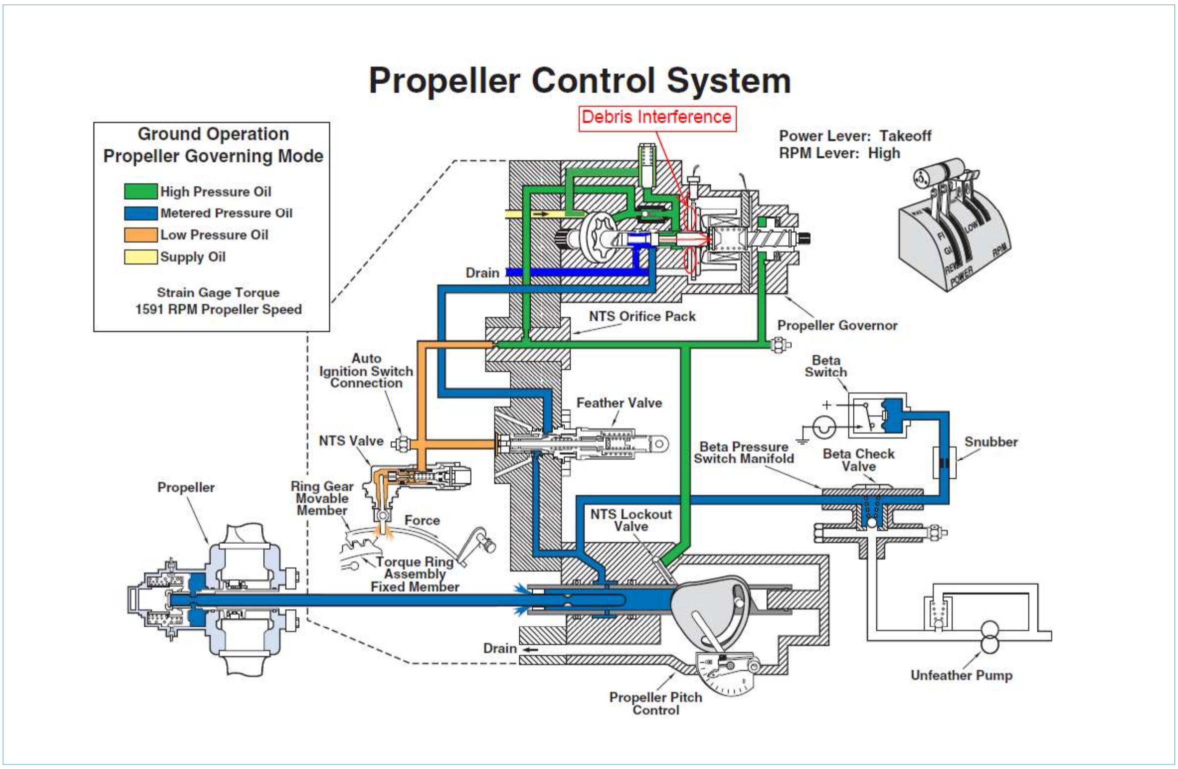


Figure 21: Propeller governor scenario with debris.

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