Air Accident Investigation Unit Ireland

SYNOPTIC REPORT

ACCIDENT
Piper PA23-250F, EI-WMN
Shannon Airport

2 December 2019

An Roinn Iompair
Department of Transport

Foreword

This safety investigation is exclusively of a technical nature and the Final Report reflects the determination of the AAIU regarding the circumstances of this occurrence and its probable causes.

In accordance with the provisions of Annex 13[1] to the Convention on International Civil Aviation, Regulation (EU) No 996/2010[2] and Statutory Instrument No. 460 of 2009[3], safety investigations are in no case concerned with apportioning blame or liability. They are independent of, separate from and without prejudice to any judicial or administrative proceedings to apportion blame or liability. The sole objective of this safety investigation and Final Report is the prevention of accidents and incidents.

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

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[1] **Annex 13**: International Civil Aviation Organization (ICAO), Annex 13, Aircraft Accident and Incident Investigation.
[2] **Regulation (EU) No 996/2010** of the European Parliament and of the Council of 20 October 2010 on the investigation and prevention of accidents and incidents in civil aviation.
[3] **Statutory Instrument (SI) No. 460 of 2009**: Air Navigation (Notification and Investigation of Accidents, Serious Incidents and Incidents) Regulations 2009.

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In accordance with Annex 13 to the Convention on International Civil Aviation, Regulation (EU) No 996/2010 and the provisions of SI No. 460 of 2009, the Chief Inspector of Air Accidents, on 2 December 2019, appointed John Owens as the Investigator-in-Charge to carry out an Investigation into this Accident and prepare a Report.

Aircraft Type and Registration:	Piper Aircraft Inc. PA23-250F Aztec, EI-WMN
No. and Type of Engines:	2 x Lycoming IO-540-C4B5
Aircraft Serial Number:	27-7954063
Year of Manufacture:	1979
Date and Time (UTC)[4]:	2 December 2019 @ 16.24 hrs approximately
Location:	Runway 24, Shannon Airport, Co. Clare
Type of Operation:	Aerial Work
Persons on Board:	Crew – 1 Passengers – Nil
Injuries:	Nil
Nature of Damage:	Substantial
Commander's Licence:	Commercial Pilot Licence (CPL) Aeroplanes (A), issued by the Irish Aviation Authority (IAA)
Commander's Age:	36 years
Commander's Flying Experience:	284 hours, of which 82 were on type
Notification Source:	Shannon Air Traffic Control (ATC)
Information Source:	AAIU Report Form submitted by the Pilot AAIU Field Investigation

[4] **UTC**: Co-ordinated Universal Time. All timings in this report are quoted in UTC, which was the same as local time on the date of the occurrence.

SYNOPSIS

During the landing on Runway 24 at Shannon Airport (EINN), the nose landing gear of the Piper PA23 aircraft collapsed, causing the aircraft's two propellers to strike the runway. The aircraft came to rest on the left side of the runway. The Pilot, who was the sole occupant, was uninjured and exited the aircraft normally. There was no fire.

NOTIFICATION AND RESPONSE

The AAIU on-call duty Inspector was notified of the occurrence by Shannon ATC. The event had occurred on the active runway at Shannon Airport, and as no injuries were reported, permission was given to recover the aircraft once a detailed photographic survey had been completed. The AAIU subsequently inspected the aircraft at Shannon Airport.

1. FACTUAL INFORMATION

1.1 Preamble

The Piper PA23-250F aircraft had recently undergone extensive maintenance. When the engines were started on 29 November 2019, prior to the planned first flight of the aircraft following the maintenance visit, the Pilot noticed that the left and right alternator INOP lights had illuminated. Maintenance personnel were informed and the planned flight was cancelled to allow the defect to be rectified. The subsequent maintenance action recorded in the aircraft's technical log book noted that a broken wire from the alternator on the left engine was replaced, and that the alternator voltage regulator for the right engine was also replaced.

Three days later, on the day of the occurrence flight, the Pilot started the aircraft's engines again and observed the same alternator INOP indications. As part of the subsequent maintenance troubleshooting, the bulb was removed from the nose landing gear indication light assembly to facilitate a voltage check. Following the replacement of the alternator voltage regulator for the left engine, and the refitting of the bulb to the nose landing gear indication light assembly, the aircraft was released to service. The maintenance engineer who reinstalled the light assembly said that the green light was on (as expected), following its reinstallation. The Pilot flew the aircraft from EINN to Kerry Airport (EIKY).

The Pilot informed the Investigation that when the aircraft's landing gear was extended on the approach to EIKY, he observed that the three green landing gear indication lights illuminated, indicating that the left landing gear, right landing gear and the nose landing gear were down and locked. He said he also noted that the nose landing gear appeared to be extended when viewed in the mirror mounted on the inboard cowling of the left engine. The Pilot said that when the aircraft was at an altitude of 800 feet (ft) on the approach to EIKY, he noticed that while the indication lights for the two main landing gears were on, the indication light for the nose landing gear was flickering. He reported that he rechecked the mirror and that the nose landing gear appeared to be extended. He said that he was about to inform Air Traffic Control (ATC) at EIKY, but that the nose landing gear light came on '*steady*' and a normal landing was performed.

The Pilot said he did not inform the Operator of what had occurred before operating the aircraft on the return flight to EINN as he attributed the flickering light to the earlier removal of the lamp assembly. He said that the three green indication lights were on, as normal, during the subsequent take-off at EIKY.

1.2 History of the Flight

The aircraft took-off from EIKY at approximately 15.52 hrs and routed back towards EINN. The Pilot reported that he extended the landing gear during the approach to Runway (RWY) 24 at EINN and that all three green gear-down indication lights illuminated. He stated that he could see the nose landing gear using the viewing mirror attached to the inboard cowling on the left engine. The Pilot said that when the aircraft was at an altitude of approximately 700 ft, the indication light for the nose landing gear started to flicker. He said he continued with the approach, as he considered that the indications were the same as those he had observed on the aircraft's previous flight and that the aircraft had landed normally following that flight. The Pilot did not recall if the light came on steady prior to the landing at EINN.

The Pilot stated that as the aircraft was crossing the runway threshold, at a speed of approximately 95 knots (kts) and with the flaps extended, he reduced the engine power for landing. He said the aircraft's red landing gear warning light illuminated and the aural alert sounded, indicating that all landing gears were not down and correctly locked. The Pilot reported that at that stage the aircraft's main wheels were on the runway and that it was '*too late to go around*' (i.e. abort the landing). The Pilot said that he felt the nose landing gear collapsing and that he tried to keep the nose up by pulling back on the aircraft's control column. The nose of the aircraft dropped and the propellers struck the runway. The aircraft came to rest on the left side of the runway at approximately 16.24 hrs (**Photo No. 1**). The Pilot, who was the sole occupant, was uninjured and exited the aircraft normally. There was no fire. The Airport Fire and Rescue Service attended the scene, and as a precaution, covered the aircraft and the adjacent runway surface in a blanket of fire-retardant foam.

Photo No. 1: Final resting position of aircraft (*Shannon Airport Fire and Rescue Service*)

1.2.1 Approach to EINN

The aircraft's route, approach track, and timings for the flight to EINN, as obtained from radar data, are shown in **Figure No. 1**. At 16.07:51 hrs, the Pilot contacted Shannon Approach (Air Traffic Control), who advised that the aircraft was 10 miles to the south of EINN and was '*number one for a left turn on ILS*[5] *approach to runway two four'*. At 16.19:00 hrs, after the aircraft had completed its left turn and was travelling back towards EINN, Shannon Approach advised the Pilot that the aircraft was tracking at about '*two four zero*' and was '*paralleling the ILS*'. Shannon Approach asked if the aircraft was on a '*heading of two seventy*'. The Pilot advised he was '*on two seven zero now*'. Shannon Approach confirmed '*two seven zero to intercept*'. At 16.20:48 hrs, Shannon Approach advised the Pilot that the ILS was now to the aircraft's left and asked the Pilot if he was going to be able to capture the ILS. The Pilot said he would try. He was also asked if he could maintain VMC[6] and he said that he could. At 16.21:50 hrs, Shannon Approach advised that the aircraft was tracking to the north of the runway (right of the ILS) and asked if the Pilot wished to proceed with a visual approach. When the Pilot confirmed that he wished to continue, Shannon Approach asked if the Pilot had '*good ground contact*'. The Pilot initially replied '*not yet*', before advising that he now had sight of the runway. At 16.22:39 hrs, Shannon Approach advised the Pilot that he was '*five miles out*' and '*coming right onto final approach*'.

The Investigation asked the Pilot about the difficulties he encountered in capturing the ILS. The Pilot said that he extended the aircraft's landing gear at an altitude of approximately 2,500 ft, as the aircraft was heading (south-west) back towards the runway. The Pilot explained that he was concerned about the landing gear indications at that stage which distracted him from the ILS. Radar data indicates that the aircraft's ground speed was approximately 116 kts[7] at the time.

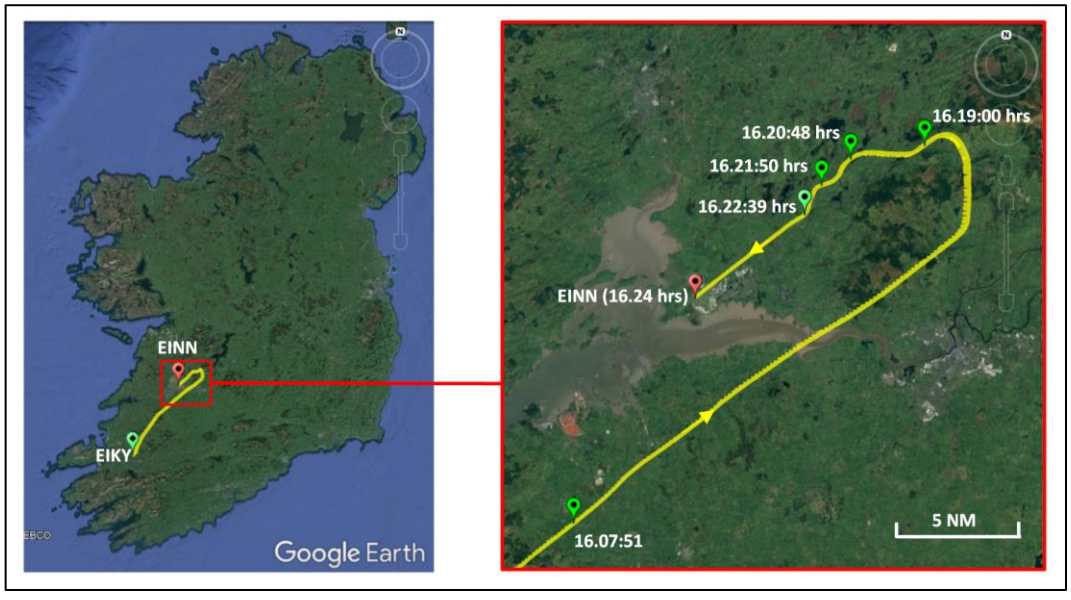

Figure No. 1: Aircraft's route, approach track, and ATC timings

[5] **ILS**: Instrument Landing System. A precision runway approach aid utilising two radio beams which together provide vertical and horizontal guidance during an approach to land.
[6] **VMC:** Visual Meteorological Conditions.
[7] The Pilot Operating Handbook (POH) for the aircraft states that the maximum gear operating speed, VLO, and the maximum gear extended speed, VLE, are both 132 kts (indicated airspeed).

1.3 Injuries to Persons

No injuries were reported to the Investigation.

1.4 Damage to Aircraft

The tips of both propellers were bent rearwards and the lower surface of the aircraft's nose section sustained abrasion damage. In addition, both engines sustained shock loading. The subsequent repairs to the aircraft were delayed due to the Covid-19 pandemic, and the aircraft did not return to service following the occurrence until November 2021.

1.5 Personnel Information

The Pilot held a CPL (A), which was issued by the IAA on 26 October 2018. The licence contained an MEP (Multi-Engine Piston) and an ME IR (Multi-Engine Instrument Rating) SPA (Single Pilot Aeroplanes), both of which were valid until 31 October 2020. The licence also contained an SEP (Single Engine Piston) (Land) rating that was valid until 31 March 2021. The Pilot's Class 1 Medical Certificate was issued by an IAA-approved Aeromedical Examiner on 12 August 2019 and was valid until 20 August 2020. The Pilot's flying experience is outlined in **Table No. 1**.

Total all types:	284 hours
Total on type:	82 hours
Total on type P1:	48 hours
Last 90 days:	49 hours
Last 28 days:	16 hours
Last 24 hours:	1.5 hours

Table No. 1: Pilot's flying experience

1.6 Aircraft Information

1.6.1 General

The Piper PA23-250F (Aztec), low-wing, all-metal aircraft was manufactured in 1979. The aircraft type is powered by two Lycoming IO-540-C4B5 six-cylinder, horizontally opposed reciprocating engines, each fitted with a constant-speed, two-bladed, aluminium alloy Hartzell propeller. The aircraft type is fitted with a retractable tricycle landing gear and trailing edge flaps, both of which are hydraulically operated. The nose landing gear retracts rearward into the nose section and each main landing gear retracts forward into the engine nacelles. Landing gear doors are fitted which are also hydraulically operated and completely cover each landing gear when retracted. When extended, the nose landing gear can be viewed from the cockpit for correct extension using a mirror located on the inboard side of the left engine cowling. The aircraft's maximum take-off weight is 5,200 pounds (2,359 kilogrammes).

1.6.2 Airworthiness Certification

The subject aircraft's Certificate of Airworthiness (C of A) was issued by the IAA on 10 October 2017. The Airworthiness Review Certificate (ARC) was issued by an IAA-approved Continuing Airworthiness Management Organisation (CAMO) on 28 November 2019 and was valid until 9 October 2020.

1.6.3 Landing Gear Indication and Warning System

The position of the landing gear is indicated by four lights located in a panel on the cockpit pedestal (**Figure No. 2**).

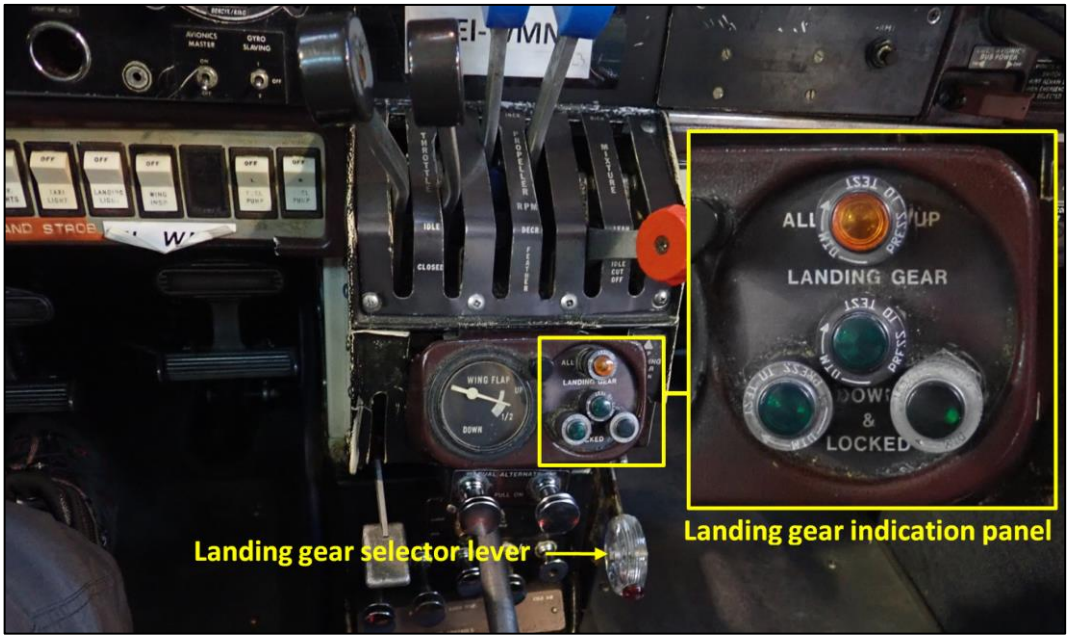

Figure No. 2: Landing gear control and indication

Each of the three green 'DOWN & LOCKED' lights indicates that its respective landing gear leg is down and locked. A single amber 'ALL UP' light indicates that all three landing gear legs are up and the gear doors are closed. When all lights are extinguished, it indicates that the landing gear is in an intermediate position. Each of the four lights incorporates a press-to-test feature, and may be dimmed or brightened by rotating the light bezel clockwise or counter-clockwise.

A red light in the landing gear selector lever flashes when the gear is up and power from one engine is reduced below 14 to 15 inches of manifold pressure[8]. When power from one engine is reduced below 10 to 12 inches of manifold pressure and the gear is up, a warning horn (aural alert) will sound in the cockpit.

[8] **Manifold Pressure:** This provides an indication of engine power/throttle position. The pressure (suction) is indicated by the aircraft's manifold pressure gauge, which is graduated in inches of mercury.

1.6.4 Aircraft Hydraulic System and Landing Gear Operation

1.6.4.1 General

The hydraulically operated landing gear and flaps on the aircraft utilise a '*powerpak*' unit located in a pedestal below the main instrument panel in the cockpit (**Figure No. 3** shows a schematic diagram of the hydraulic system).

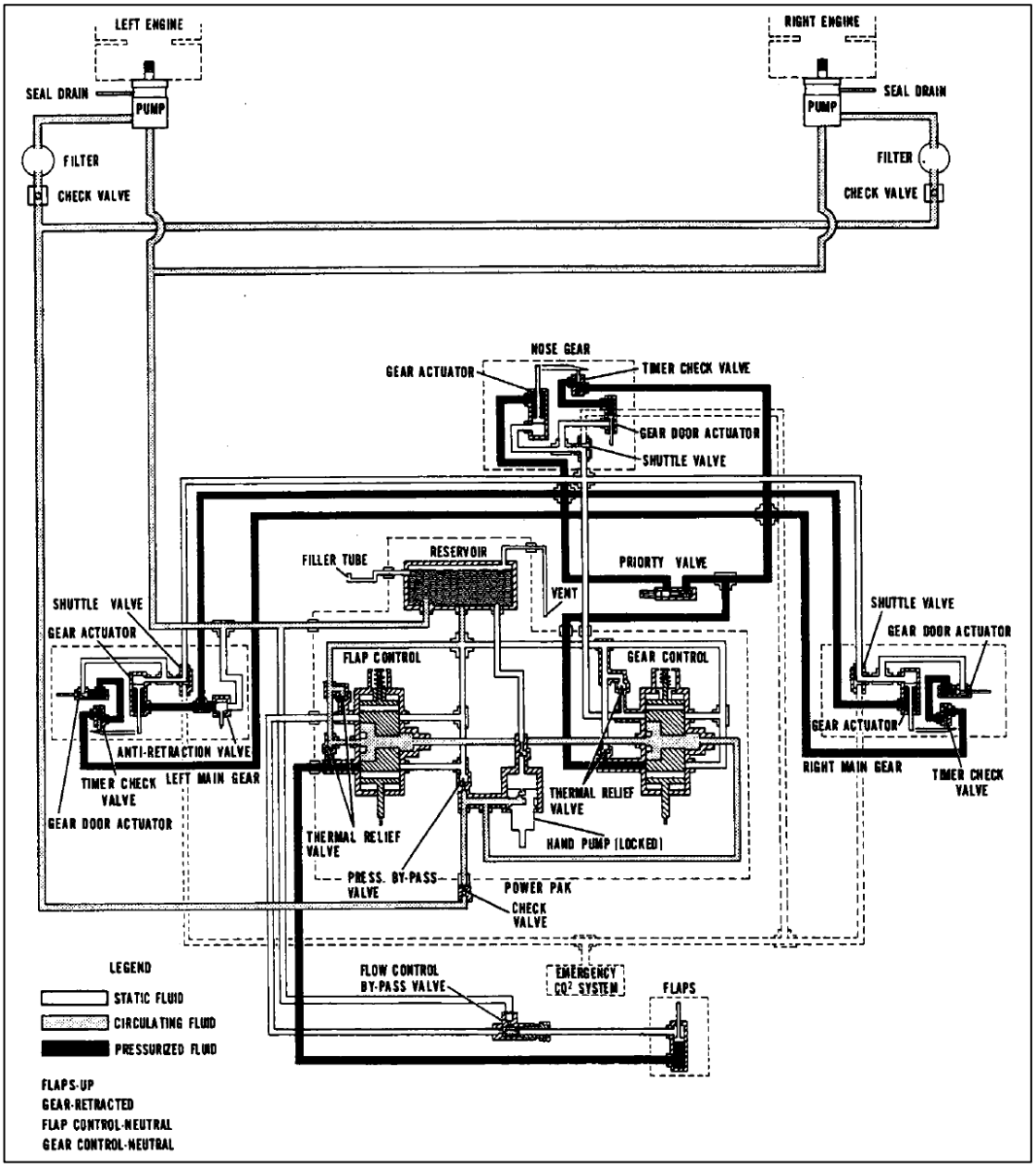

Figure No. 3: Hydraulic system schematic (*Piper Aztec Service Manual*)

The operation of the *powerpak* is controlled by a landing gear selector lever and a flap selector lever, both of which are connected directly to the *powerpak* and protrude through the face of the pedestal in the cockpit. The *powerpak* also serves as a hydraulic reservoir. Pressure for the hydraulic system is supplied by a hydraulic pump fitted to each engine (some PA23 aircraft are fitted with one pump only). Each pump is rated to deliver 25-45 US gallons per minute at a maximum operating pressure of 1,500 pounds per square inch (psi). A filter is fitted downstream of each engine-driven pump. A hand pump is fitted to the *powerpak* for use if the engines or engine-driven pumps fail.

1.6.4.2 Landing Gear Operation

When the landing gear selector lever is in the neutral position, fluid travels through the landing gear selector ports and back to the reservoir. When the landing gear selector lever is moved to the DOWN (extend) position, it is locked in place by the action of a spring and detent assembly in the *powerpak*. The selector lever is attached to a camshaft within the *powerpak*; the camshaft opens and closes poppets (valves) that control the flow of fluid to the landing gear extension/retraction actuators. As fluid pressure builds up on the down/extend side of the piston within its actuator, fluid is forced from the up/retract side of the piston through the selector return port and back into the reservoir. A priority valve located in the pedestal prevents the reverse flow of hydraulic fluid to the reservoir until a pressure of 600 psi has built up in the cylinders. The gear doors, with no pressure restriction, open first. When each actuator piston has moved as far as possible, fluid pressure builds up in the down/extend side, until it reaches a specific pressure. At this stage, the pressure forces the plunger of the *powerpak*'s detent assembly up against its spring, relieving the holding pressure from the camshaft. The camshaft return spring then forces the camshaft and landing gear selector lever to the neutral position, thus trapping fluid under pressure in the down/extend side of the actuators and keeping the mechanical down-locks on each landing gear firmly engaged.

The nose landing gear extension/retraction actuator is connected to the down-lock latch assembly through the down-lock link, and also to the upper drag link (**Figure No. 4**). When the landing gear selector lever is moved to the UP (retract) position, the initial retraction of the actuator pulls on the down-lock link, thereby disengaging the down-lock latch and permitting the actuator to retract the gear. A nose landing gear indicating switch is fitted to the upper drag link. The switch is actuated by the down-lock latch hook (**Section 1.7.2.2**). A timer check valve (sequence valve) is installed for each landing gear, to prevent the gear doors from closing until each landing gear has fully retracted.

A strut-actuated bypass valve is fitted to the left main landing gear, which prevents the landing gear from retracting when the weight of the aircraft is on the gear. This valve is open when the strut is compressed and bypasses all hydraulic fluid on the pressure side of the system to the return side, preventing any pressure build up in the retraction system. When the oleo strut is extended, as in flight, or when the aircraft is on maintenance jacks, the valve is closed, permitting the system to operate as normal. A mechanical latch is also incorporated at the landing gear selector lever to guard against inadvertent retraction of the landing gear while the aircraft is on the ground. The mechanical latch must be operated before the selector lever can be moved upward.

An independent emergency landing gear extension system, which utilises pressurised carbon dioxide, is also installed, to extend the landing gear if the hydraulic system fails due to pipe breakage or *powerpak* malfunction. When the system is operated, pressurised carbon dioxide flows from a cylinder through separate lines to shuttle valves adjacent to the gear actuating cylinders. The gas pressure opens the shuttle valves, allowing carbon dioxide to enter the gear cylinders and extend the gears.

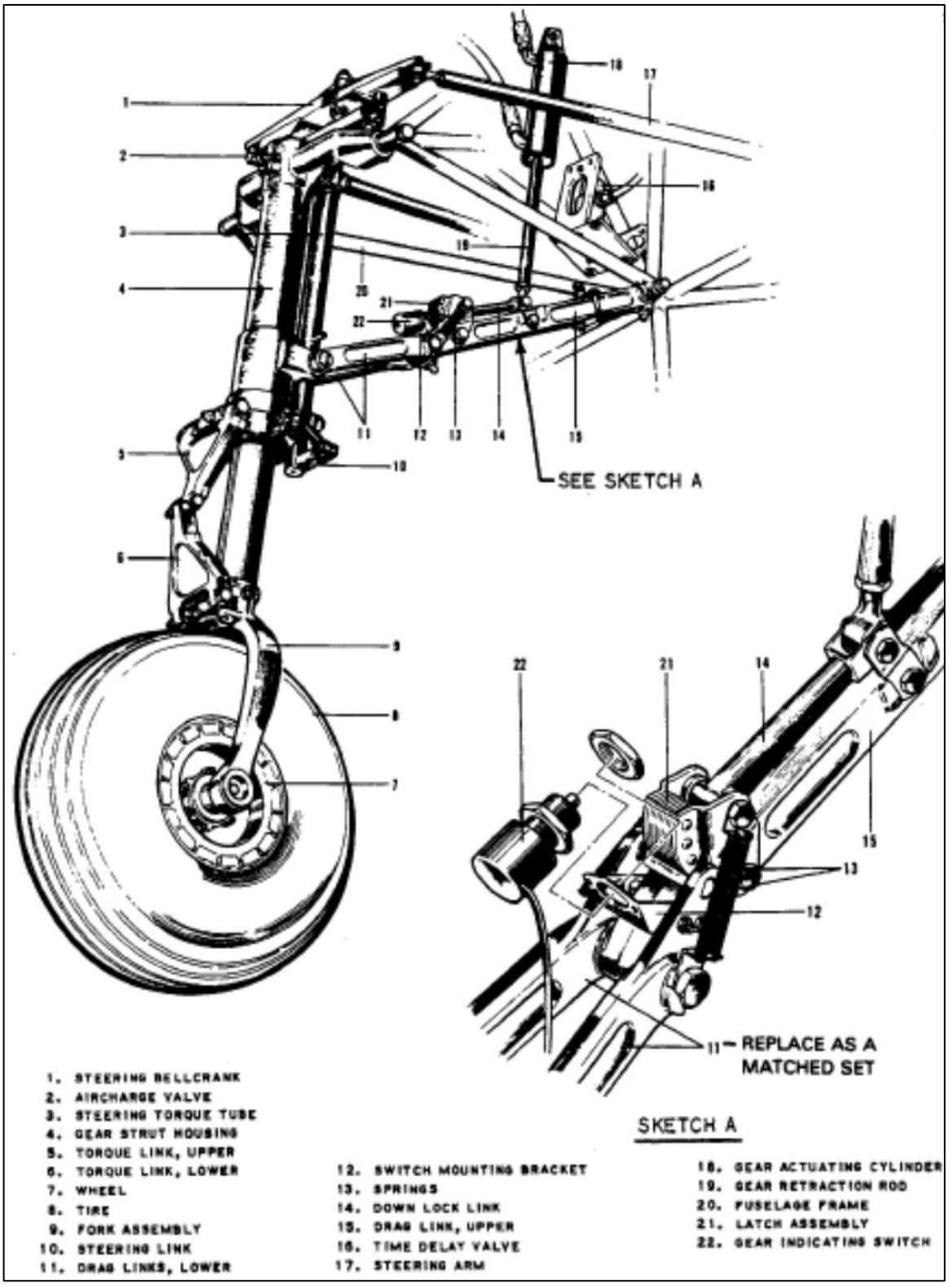

Figure No. 4: Nose Landing Gear (*Piper Aztec Service Manual*)

1.6.5 Maintenance History

The aircraft underwent extensive scheduled maintenance that was certified on 28 November 2019, including 50-hour, 100-hour, 200-hour, 400-hour, 440-hour, 500-hour, 1,000-hour, 1-month, 4-month, 12-month and 7-year inspection items, and also inspections related to applicable Airworthiness Directives. The left engine was replaced during the maintenance visit. Its replacement was certified on 25 November 2019.

Numerous inspection tasks relating to the hydraulic system and the landing gear were completed during the maintenance visit: several hydraulic hoses were replaced; the landing gear warning horn and light were checked for correct function; the down-locks were inspected for correct operation and adjustment; the operation of the landing gear retraction system was also checked, as was the position and security of the indicating switches and electrical leads. The engine-driven hydraulic pumps were due to be replaced; however, as replacement parts were unavailable at the time of the maintenance visit, maintenance personnel applied to the company's Continuing Airworthiness Manager (CAM) for a 100-hour extension. The CAM reviewed and approved the extension request in accordance with the Operator's IAA-approved continuing airworthiness system. When the left engine hydraulic pump was subsequently removed and sent for overhaul (following the occurrence), the overhaul agency noted that the '*bearings and gear* [had] *locked up on the shaft*'

As outlined in **Section 1.1**, immediately prior to the flight to EIKY, the bulb was removed from the nose landing gear indication light assembly to facilitate a voltage check in order to troubleshoot an alternator INOP indication, following which the bulb was refitted.

1.7 Post-Occurrence Inspections

1.7.1 General

When one of the Operator's aircraft maintenance engineers examined the aircraft immediately after the occurrence, he recalled that the landing gear selector lever was in the neutral position. The engineer also stated that when the aircraft was lifted during the subsequent recovery operation and the nose landing gear was extended by using the emergency hand pump, the green nose landing gear indication light flickered when the light bezel was moved.

The aircraft Operator's maintenance personnel examined the aircraft on 13 December 2019 in the presence of the Investigation, in an attempt to establish a possible cause of the occurrence. The adjustment of the nose landing gear indicating switch was examined and appeared to be within Service Manual limits. An electrically powered hydraulic test rig was used to generate hydraulic pressure to permit retraction and extension of the landing gear. Numerous extensions and retractions were performed with no defects noted. However, it was noted that at hydraulic fluid flow rates above five gallons per minute (the flow rate of each engine-driven pump is 25-45 gallons per minute), it was possible to physically prevent the nose landing gear from fully extending by pushing on the gear as it was pivoting forwards. This caused the landing gear selector lever to return to the neutral position, with the result that the main landing gears reached the down and locked position, whereas the nose landing gear remained unlocked. The Operator stated that the same test was subsequently performed on another PA-23 aircraft, with the same result.

It was also noted that the when the landing gear selector lever was moved to the DOWN (extend) position and the three landing gears extended, the green 'DOWN & LOCKED' indication light for the nose landing gear illuminated first, followed by the right main landing gear indication light and then the left main landing gear indication light. When the gear was selected to the UP (retract) position, the green indication light for the nose landing gear extinguished first and the nose landing gear was the first to move towards the retract position.

1.7.2 Examination of Down-Lock and Drag Link Assembly

1.7.2.1 Examination Prior to Removal

An examination of the operation of the nose landing gear, including its down-lock assembly and indicating switch was performed in the presence of the Investigation, in order to establish the conditions that could cause the nose landing gear green 'DOWN & LOCKED' indication light to flicker. It was found that if the landing gear was slowly extended, using the emergency hand pump, until the down-lock had almost locked and the nose landing gear down indicating switch had just actuated the indication light, it was possible to physically force the drag links up and down, which caused the indication light to flicker on and off. It was not possible to make the light flicker when the gear was down and locked (latch fully engaged). However, when the gear was down and locked and the landing gear select lever had returned to the neutral position, it was possible to '*break*' the down-lock by pushing the drag links upwards. It was also noted that when the landing gear was selected to the UP (retract) position, the landing gear selector lever did not return to the neutral position as required following the retraction of the gear.

1.7.2.2 Examination Following Removal

The nose landing gear drag link assembly, to which the down-lock latch assembly and nose landing gear down indicating switch are fitted, was removed from the aircraft for further examination (**Photo No. 2**).

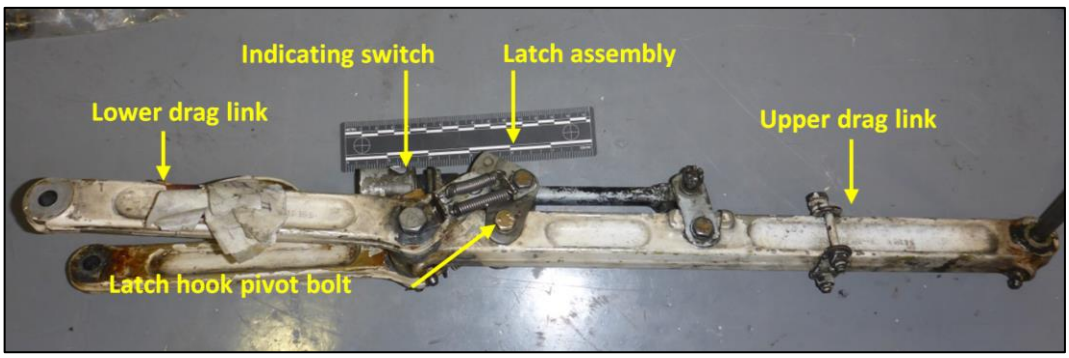

Photo No. 2: Nose landing gear down-lock latch and drag link assembly

The down-lock latch hook, which is part of the latch assembly, is fitted to the upper drag link and is spring-loaded towards the locked position. During the final stages of gear extension, the latch receiver, which is attached to the lower drag link, slides down the lower part of the outside face of the latch hook (**Photo No. 3**). When the receiver moves beyond the end of the outside face of the hook, the hook closes (**Photo No. 4**) and is held closed by the action of the springs fitted to the latch and by the downward force exerted by the extension/retraction actuator.

During examination of the switch operation, with the drag link assembly removed from the aircraft, it was found that when the latch hook was manually pulled back towards the unlocked position, the indicating switch could be heard to open before the latch was fully unlocked and could be heard to close before the latch was in the fully locked position (**Photo No. 5**).

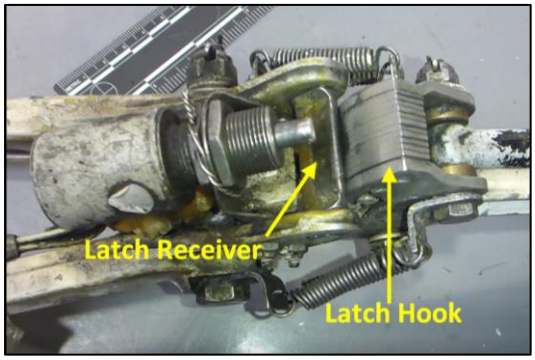

Photo No. 3: Latch assembly with latch receiver in contact with latch hook, prior to locking

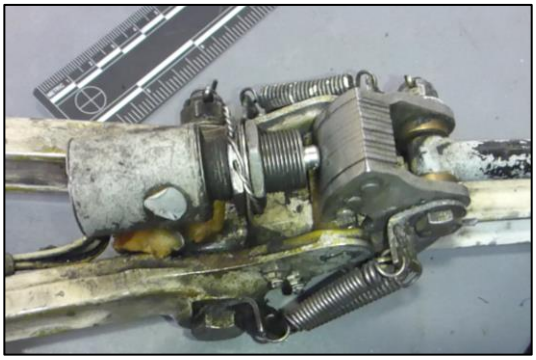

Photo No. 4: Latch assembly in fully locked position

Photo No. 5: Latch at switch actuation position

During further examination of the drag links and down-lock latch assembly, significant free play was found in the latch hook pivot. In addition, damage was noted on the upper drag link, which appeared to have been caused by contact with the latch assembly when it was in the unlatched position. When the pivot bolt (circled in red in **Figure No. 5**) was removed to identify the cause of the free play, it was noted that the machined hole in the upper drag link was larger than the diameter of the bolt. The Investigation notes that it would be difficult to identify this free play when the drag link assembly, down-lock latch assembly, and associated springs are installed on the aircraft.

Subsequent investigation found that the upper drag link fitted was for an older serial number aircraft, and had a larger diameter hole than the correct drag link. Maintenance records indicate that the drag link assembly was not removed during the maintenance visit conducted prior to the flight from EINN to EIKY. The Operator reviewed the technical records for the aircraft but it could not be determined when the incorrect assembly had been installed. Subsequent to the occurrence, the entire nose landing gear drag link assembly and the down-lock latch assembly were replaced.

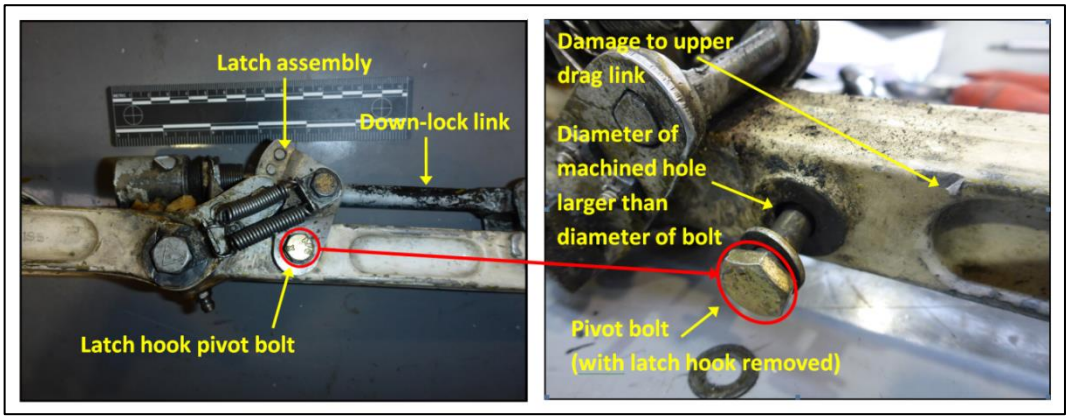

Figure No. 5: Latch assembly pivot

1.7.3 Internal Pressure Leakage Tests

A further aircraft examination, in the presence of the Investigation, was performed on 9 January 2020. Pressure gauges were fitted to the landing gear extension and retraction hydraulic circuits in accordance with Section 6-16 ('*Internal Leakage Checks*') of the aircraft's Service Manual, to determine if the correct hydraulic pressures were being maintained during landing gear extension and retraction.

It was noted that when the landing gear was selected to the DOWN (extend) position, the pressure in the down line increased to approximately 1,400 psi until the gear was down and locked and the landing gear selector lever had returned to the neutral position, and then reduced over the course of the next 30 seconds approximately, to less than 400 psi and eventually fell to 300 psi. At this stage, the pressure in the retract line was approximately 200 psi. The Service Manual states that:

> '[…] *select gear DOWN. Allow the selector handle to return to neutral and note pressure reading over a 10 minute period. As the selector lever returns to neutral, the pressure reading on either gauge will drop slightly and then should stabilize. Once the pressure drop has stabilized, a further drop should not be indicated. Under no circumstances should the initial pressure drop below 700 psi. A slow decrease in pressure or a droppage below 700 psi indicates a possible internal leak in the landing gear section of the powerpak or one of the components in the landing gear portion of the hydraulic system*'.

1.7.4 Powerpak Examination

As a result of the pressure drop observed during testing as outlined above, the *powerpak* was removed from the aircraft by the Operator and sent to an approved repair organisation located in the United States (US) to undergo bench testing prior to being dismantled and examined. All work was carried out in the presence of a Federal Aviation Administration (FAA) representative, acting on behalf of the US National Transportation Board (NTSB) and the AAIU.

The repair organisation removed the hydraulic reservoir from the *powerpak* and visually inspected the *powerpak* for contamination. None was found. Before the unit was bench-tested, it was noticed that the workshop-adjustable release detent screws for the landing gear selector lever and the flap selector lever had been unscrewed by approximately half an inch.

During bench-testing, it was observed that when selected to the DOWN (extend) position, the landing gear selector lever returned to the neutral position at 1,300-1,350 psi, which the repair organisation deemed acceptable (the pressure range specified in the Service Manual is 1,250 psi (+50 psi, -0 psi). When selected to the UP (retract) position, the landing gear selector lever did not return to the neutral position within the same specified pressure range. The repair organisation attributed this to the detent spring screw being unscrewed.

The unit was disassembled. A small piece of rubber was found at the return side of the gear-up poppet valves, but the repair organisation deemed this to be not significant to the occurrence. No other defects were found.

The repair organisation concluded that the unit was operating in accordance with the Service Manual and was '*holding pressure*'. The repair organisation considered the possibility of pressure leaking into the up/retract side of the system when the gear selector lever was in either the DOWN (extend) or neutral position; the repair organisation noted that, due to the design of the *powerpak*, '*there is no possible way for that to occur*'. Another area considered was the possibility of a loss of pressure in the down/extend side of the landing gear hydraulic system. The repair organisation identified a possible cause of such a pressure loss – the repair organisation noted that because the detent screw had been unscrewed, it could have caught on the mounting bracket for the *powerpak* as the landing gear selector lever returned to the neutral position, causing the camshaft to prevent the poppet valves on the down/extend side from completely closing. The repair organisation deemed this scenario to be possible, but '*extremely unlikely*'. The Operator installed a replacement *powerpak*.

1.7.5 Examination of Other Components and Hydraulic Fluid

The Operator inspected several other landing gear/hydraulic system components: The nose landing gear extension/retraction actuator was removed, dismantled, inspected, reassembled, refitted and tested; no defects were noted. The priority valve and the shuttle valves (left main landing gear, right main landing gear, and nose landing gear) were removed, tested and refitted; no defects were noted. The nose landing gear strut/oleo was removed, disassembled, cleaned and inspected. Both engine-driven hydraulic pumps were replaced. In addition, a sample of hydraulic fluid from the aircraft was analysed by a specialist laboratory; this identified the presence of particles and non-ferrous debris. The Operator performed a flushing of the hydraulic system and scheduled a repeat inspection of the hydraulic filters to be carried out after 10 hours of aircraft operation. This was carried out, as required, on 21 December 2021 and no adverse findings were noted. New filter elements were installed.

1.7.6 Examination of Nose Landing Gear Indication Light Assembly

The Operator's maintenance personnel also removed the nose landing gear down indication light assembly from the panel in the cockpit pedestal and noted that the soldered joints between the electrical wiring and the bulb fitting were in poor condition (**Photo No. 6**). It could not be established when these connections had been soldered/repaired.

Photo No. 6: Condition of soldered joints (circled) at nose landing gear indication light fitting

1.8 Subsequent Flights

After the occurrence, the Operator carried out extensive maintenance and repair work in addition to scheduled maintenance checks. Following the completion of this work, the aircraft was first flown on 22 November 2021. The Operator reported that several flights were subsequently flown and that the landing gear and its indication system operated normally.

The Investigation asked the Operator to note the order that the green landing gear-down indication lights illuminated after the landing gear selector lever was moved to the DOWN (extend) position during flight. The Operator advised that a flight crew consisting of two pilots noted that the main landing gear deployed first followed by the nose landing gear, and that this was based on observing the illumination sequence of the indication lights and also what they could feel.

On 12 January 2022, the Operator informed the Investigation that following a take-off from EINN that morning, the nose landing gear would not retract. The Operator noted that during subsequent troubleshooting using an electrically powered hydraulic test rig connected while the aircraft was on maintenance jacks, the nose landing gear appeared to extend first followed by the main landing gears but that the main landing gear locked into final position before the nose landing gear became locked.

Maintenance inspections following the 12 January 2022 event found evidence of hydraulic leaks at the left-hand hydraulic filter housing and at a check valve (non-return valve) at the *powerpak*, and also a low hydraulic quantity. Further examination found contamination in the left-hand and right-hand hydraulic filters. Both engine-driven hydraulic pumps were removed and sent for overhaul. The Operator advised the Investigation that the left-hand pump was found to be unserviceable, whereas the right-hand pump was found to be serviceable. Due to the contamination found, the Operator sent several hydraulic components for workshop inspection, cleaning, and operational checks, including the landing gear extension/retraction actuators, the landing gear door actuators, the shuttle valves, the priority valves, the anti-retraction valve, and the flap actuator. The Operator also performed a flushing of the hydraulic system. All components were refitted, the *powerpak* was replaced, and an operational check of the landing gear was performed. No defects were noted and the aircraft was returned to service. The Operator was of the opinion that a low hydraulic quantity resulted in cavitation and damage to the left-hand hydraulic pump, which resulted in contamination of the hydraulic system, causing the nose landing gear not to retract on 12 January 2022.

1.9 Meteorological Information

Met Éireann, the Irish Meteorological service, provided the Investigation with the following meteorological information:

At the time of the occurrence, there was an anticyclone of 1033 hPa[9] centred approximately 90 nautical miles south of Roches Point (south of Cork Harbour) which generated a light to moderate variable airflow over the country. The surface wind was south-east at 6 knots (kts); the wind at 2,000 feet (ft) was south-west at 15 kts; and the wind between the surface and 300 ft was variable at 5-8 kts. Weather conditions were misty, with a visibility of 6,000 metres (m). Cloud conditions were 1-2 oktas[10]. The surface temperature and dew point were 4 and 3 degrees Celsius respectively.

1.10 Aerodrome Information

The event occurred on RWY 24 at EINN, which is 3,199 m long and 45 m wide.

1.11 Recorded Data

The aircraft was not fitted with a Cockpit Voice Recorder (CVR) or a Flight Data Recorder (FDR), nor was it required to be. However, ATC audio and radar recordings for the flight, and data from the Pilot's portable navigation device were made available to the Investigation.

2. ANALYSIS

2.1 Introduction

Aircraft with retractable landing gear are generally fitted with indication and warning systems to indicate the status of the landing gear (retracted/extended) and to warn if the gear has not been selected to the DOWN (extend) position prior to landing. It is vital that these systems provide reliable and trusted indications.

In this case, just before the aircraft operated from EINN to EIKY on its first flight following the completion of extensive maintenance, the bulb from the nose landing gear indication light assembly was removed and refitted by maintenance personnel during troubleshooting for an alternator INOP indication. During the approach to EIKY, with the landing gear selected to the DOWN (extend) position, the Pilot said he noticed that the green indication light for the nose landing gear was flickering, but that the nose landing gear appeared to be extended when viewed in the mirror affixed to the inboard cowling of the left engine. The Pilot reported that the nose landing gear indication light then came on '*steady*' and a normal landing was performed. The Pilot said he attributed the flickering light to the earlier removal of the lamp assembly and therefore did not inform the Operator of what had occurred before operating the aircraft on the return flight to EINN. The Pilot also said the landing gear green indication lights were on, as normal, during the take-off from EIKY.

[9] **hPa:** Hectopascals – units of pressure.
[10] **Okta:** A unit used to express the extent of cloud cover equal to 1/8 of the sky.

During the approach to EINN, when the green indication light for the nose landing gear reportedly started to flicker, the Pilot, whose confidence in the landing gear indication and warning system may have been undermined, said he continued with the approach, as he could see the extended nose landing gear in the mirror and considered that the indications were the same as those he had observed during the approach to EIKY. However, unlike the approach to EIKY, the Pilot did not recall that the light came on steady. The Pilot continued with the landing. As evidenced by the reported sounding of the aural alert and the illumination of the red light in the landing gear selector lever, when the engine power was reduced in the final moments of the landing, the reported flickering green light was actually providing an accurate indication that the nose landing gear was not fully down and locked. This resulted in the nose landing gear collapsing when the nose of the aircraft was lowered during the landing.

2.2 Technical Aspects

The nose landing gear is fitted with a single actuator which operates the down-lock latch assembly and also extends and retracts the landing gear. The initial movement of the actuator during the retraction process causes the down-lock link to unlatch the down-lock latch assembly. The actuator continues to move and retract the gear by pulling on the upper drag link. When the landing gear is in the DOWN (extend) position, the hydraulic system is designed to maintain hydraulic pressure on the down/extend side of the extend/retract actuator, thereby keeping a downward force on the upper drag link and also keeping the mechanical down-lock latch firmly engaged.

During post-occurrence examination of the aircraft, and with all components still installed, the Investigation established that it was not possible to cause the nose landing gear green indication light to flicker when the down-lock latch was fully engaged, i.e. it could only be induced to flicker when the latch was not fully engaged. Therefore, on the aircraft's approach into EINN when, reportedly, the nose landing gear green indication light was flickering, the nose landing gear down-lock latch assembly was likely not fully engaged, and although the gear may have appeared to be extended in the viewing mirror, it was not fully down and locked, as evidenced by its subsequent collapse when weight was applied during the landing.

2.2.1 Possible Failure Scenarios

For the nose landing gear down-lock latch assembly to have not been fully engaged in flight, when the landing gear had been selected to the DOWN (extend) position, it either did not reach the locked position, or it reached the locked position and then somehow unlocked. Several possible reasons for this to occur were considered by the Investigation:

- A defective *powerpak*
    - Anomalies in the pressure difference between the down/extend side of the hydraulic system and the up/retract side with the landing gear in the DOWN (extend) position;
    - Premature return of the landing gear selector lever to the neutral position following a selection to extend the gear)
- Free play in the latch hook pivot

- Air in the hydraulic system
- A defective left-hand engine-driven hydraulic pump
- Timing of landing gear selection

In addition, the soldered joints between the electrical wiring and the nose landing gear down indication light fitting were found to be in poor condition during post-occurrence inspection. This could result in the nose landing gear down indication light flickering when the light is powered, i.e. when the nose landing gear is down. Therefore, the Investigation considered if this could also have been a factor in the occurrence.

2.2.2 Powerpak Issues

2.2.2.1 Anomalies in the Pressure Difference between the Down and Up Sides of Hydraulic System

During post-occurrence system testing conducted in the presence of the Investigation, it was observed that when the landing gear was selected to the DOWN (extend) position, and after the landing gear selector lever had returned to the neutral position, the pressure in the down/extend side of the system reduced to less than 400 psi over the course of approximately 30 seconds and then continued to drop, eventually reaching 300 psi. The aircraft Service Manual states that '*under no circumstances should the initial pressure drop below 700 psi'* and that *'a slow decrease in pressure or a droppage below 700 psi indicates a possible internal leak in the landing gear section of the powerpak or one of the components in the landing gear portion of the hydraulic system*'.

The Pilot reported that during the approach to EIKY on the previous flight, all three landing gear green indication lights illuminated after the gear was selected to the DOWN (extend) position. The Pilot said that at an altitude of 800 ft, while the indication lights for the two main landing gears remained on, the indication light for the nose landing gear was flickering, before coming on steady just before landing. For the nose landing gear down-lock latch assembly to have been locked, before somehow moving towards the unlocked position (which could result in the light being on, before starting to flicker), the pressure in the down/extend side of the hydraulic system would have had to reduce below the pressure in the retract side. This could cause the extension/retraction actuator to move in the retract direction and unlock the latch. During post-occurrence testing, it was noted that the nose landing gear was the first gear to move when the landing gear selector lever was moved to the UP (retract) position and therefore the nose landing gear would likely be the first to unlock in the event of an adverse pressure difference. However, although the pressure in the down/extend side was found to drop during system testing as outlined above, it did not reduce below that of the retract side. Therefore the Investigation considers this scenario unlikely.

It is also possible that during the extend cycle, the nose landing gear down-lock latch reached a position where it was just actuating the switch but had not yet reached the fully locked position (**Photo No. 5**). Such a position could cause the indication light to be on, off or to flicker. During the approach to EIKY, the latch appears to have eventually reached a position whereby it caused the indication light to come on steady and the nose landing gear to lock in the DOWN (extend) position, as evidenced by the normal landing. However, the collapse of the nose landing gear on landing at EINN indicates that the latch must have been unlocked.

The approved repair organisation that tested and dismantled the *powerpak* following the occurrence concluded that the unit was operating in accordance with the Service Manual and was '*holding pressure*'. However, the repair organisation identified a possible reason for the pressure loss observed during the examination conducted on the aircraft prior to the *powerpak* being removed. The repair organisation noted that because a detent screw on the *powerpak* had been unscrewed, it could have caught on the mounting bracket for the *powerpak* as the landing gear selector lever returned to the neutral position, causing the camshaft within the unit to prevent the down/extend side poppet valves from completely closing and resulting in a pressure loss on the down/extend side. The repair organisation deemed that this scenario, although possible, was '*extremely unlikely*'. The repair organisation also stated that it was not possible for pressure to transfer from the down/extend side of the *powerpak* to the up/retract side, due to the design of the unit.

The approved repair organisation found a small piece of rubber at the return side of the gear-up poppet valves, which the organisation deemed to be not significant to the occurrence. Separately, laboratory analysis of the hydraulic fluid identified the presence of particles/debris. Although the location of the piece of rubber at the time of the *powerpak* examination was deemed by the repair organisation to be not significant, the presence of any foreign matter in a hydraulic system has the potential to adversely affect its operation.

2.2.2.2 Landing Gear Selector Lever

When the landing gear selector lever is moved from the neutral position to the DOWN (extend) position, it should automatically return to the neutral position when the hydraulic pressure in the down/extend side is within a specified range. This should also occur when the selector lever is moved to the UP (retract) position. During post-occurrence examination of the aircraft, conducted in the presence of the Investigation, it was noted that with a hydraulic test rig connected, and the aircraft supported by maintenance jacks, the landing gear selector lever did not return to the neutral position when the landing gear was selected to UP (retract) and the gear had fully retracted.

When the gear was extended with the hydraulic test rig adjusted to a flow rate above five gallons per minute (the flow rate of each engine-driven pump is 25 to 45 gallons per minute), it was possible to prevent the nose landing gear from fully extending by physically pushing on the gear as it was pivoting forwards. This caused the landing gear selector lever to return to the neutral position, with the nose landing gear remaining unlocked. Aerodynamic loads experienced by the extending nose landing gear in-flight may have had a similar effect. Although the same test was subsequently performed on another PA-23 aircraft, with the same result, it showed that it was possible for a selector lever to return to the neutral position before the nose landing gear was fully down and locked. It should be noted that maintenance personnel observed that the landing gear selector lever was found to be in the neutral position following the occurrence, yet the nose landing gear was evidently unlocked.

2.2.2.3 Powerpak Summary

As a result of the anomalies identified with the *powerpak*, the Investigation considers that it may have been a factor in the occurrence.

2.2.3 Free Play in the Latch Hook Pivot

During the Investigation's post-occurrence examination of the aircraft, it was identified that the machined hole in the upper drag link was larger than the diameter of the latch hook pivot bolt. This resulted in significant free play in the latch hook pivot. Subsequent investigation found that the upper drag link fitted was for an older serial number aircraft, and had a larger diameter hole than the correct drag link. Maintenance records indicate that the drag link assembly was not removed during the maintenance visit conducted prior to the flight from EINN to EIKY. The Operator reviewed the technical records for the aircraft but it could not be determined when the incorrect assembly had been installed.

The damage noted on the upper drag link was likely as a result of the free play, which may have permitted the latch hook to move beyond its designed limit when unlocked, allowing it to make contact with the upper drag link.

The Investigation considered the possibility that the free play might also have adversely affected the correct operation of the latch. However, although it could not be determined when the incorrect drag link had been installed, it was likely installed on the aircraft for some time before the accident flight. According to the Operator, there had been no previous reports of the nose landing gear indication lights flickering on the subject aircraft. Therefore, while it cannot be definitively ruled out, the Investigation considers it unlikely that the free play in the latch assembly pivot, on its own, resulted in the nose landing gear failing to lock in the down position. However, the free play may have resulted in the latch being less resistant to unlocking if hydraulic pressure was lost on the down/extend side of the nose landing gear extend/retract actuator that would normally keep the latch firmly engaged.

2.2.4 Air in the Hydraulic System

Air is compressible, and its presence in a hydraulic system can cause adverse effects. In this case, the aircraft was operating its first flight following extensive system maintenance, during the course of which, the hydraulic system was disturbed. Notwithstanding that the operation of the landing gear retraction system was checked during the maintenance visit, it is possible that following such extensive maintenance, some air remained in the system which could have adversely affected the operation of the system.

2.2.5 Defective Left Engine-Driven Hydraulic Pump

The scheduled replacement of both engine-driven hydraulic pumps was deferred in accordance with the Operator's IAA-approved continuing airworthiness system, due to the unavailability of replacement parts during the most-recent maintenance visit. When the left engine-driven hydraulic pump was subsequently removed and sent for overhaul, the overhaul agency noted that the '*bearings and gear* [had] *locked up on the shaft'.* However, some PA23 aircraft are only fitted with a single engine-driven hydraulic pump. Therefore, the Investigation considers that the defective left engine-driven hydraulic pump was unlikely to have been a factor in the occurrence.

2.2.6 Condition of Soldered Joints at Nose Landing Gear Down Indication Light Fitting

The condition of the soldered joints at the nose landing gear down indication fitting was not in keeping with normal aviation standards and had the potential to cause the indication light to flicker when the light was powered, i.e. when the nose landing gear latch assembly had actuated the switch. Therefore, the possibility that the reported flickering of the nose landing gear down indication light on the previous flight (to EIKY) being solely due to a poor electrical connection at the light fitting cannot be ruled out. However, unlike the landing at EIKY, the nose landing gear was not locked in the down position prior to the landing at EINN on the occurrence flight, as evidenced by the collapse of the gear. Nevertheless, while the Investigation considers the condition of the soldered joints not to have been causal in the actual collapse of the gear, any erosion of the Pilot's confidence in the indication system could lead to appropriate responses following a flickering gear indication light, such as a go-around or a re-selection of the landing gear, not being carried out.

2.3 Timing of Landing Gear Selection

For completeness, the Investigation considered if the timing of the landing gear selection could have been a factor in this occurrence. Apparent difficulties in capturing the ILS for RWY 27 during the approach to EINN were a potential source of distraction in the cockpit. However, the Pilot informed the Investigation that he extended the landing gear at an altitude of approximately 2,500 ft, but concerns about the landing gear indications at this stage resulted in difficulties capturing the ILS. Radar data indicates that the aircraft's ground speed was approximately 116 kts at the time. Meteorological Information provided by Met Éireann indicated that the wind at 2,000 ft was south-west at 15 kts. Therefore, the airspeed would have been approximately 131 kts, which was less than the 132 kts maximum gear operating speed, V_{LO}, and the maximum gear extended speed, V_{LE}.

The Investigation found that during system testing following the occurrence with an electrically powered hydraulic test rig connected and the aircraft on maintenance jacks, when the landing gear selector lever was moved to the DOWN (extend) position, the nose landing gear reached the down and locked position before the main landing gear. Notwithstanding this, the Operator reported that the main landing gear was the first to lock, both inflight when the aircraft had been returned to service following the subject (2 December 2019) occurrence and during system testing following the 12 January 2022 event. However, as the Operator's observations were made following extensive maintenance action on the aircraft's landing gear and on its hydraulic system, they may not have been representative of the behaviour of the landing gear at the time of the subject occurrence.

Furthermore, the reported flickering of the nose landing gear green indication light on the approach into EINN could only have occurred with the nose landing gear extended and its indicating switch actuated. Moreover, maintenance personnel informed the Investigation that the landing gear selector lever was found to be in the neutral position following the occurrence. The system design is such that, with the main landing gear down and locked, and the landing gear selector lever in the neutral position, the lever must have been moved to the DOWN (extend) position prior to landing, before the lever returned to the neutral position. Because of this and also the number of technical factors identified, the investigation considers that the timing of landing gear selection in this occurrence was not an issue.

2.4 Subsequent Issue with Nose Landing Gear

On 12 January 2022, the Operator informed the Investigation that following a take-off from EINN that morning, the nose landing gear would not retract. Subsequent troubleshooting found evidence of two hydraulic leaks, a low hydraulic quantity, and contamination in the hydraulic filters. The engine-driven hydraulic pumps were removed and sent for overhaul, which identified the left-hand pump to be unserviceable. The Operator was of the opinion that the low hydraulic quantity resulted in cavitation and damage to the left-hand hydraulic pump, which resulted in contamination of the hydraulic system, causing the nose landing gear not to retract on 12 January 2022.

Following the subject (2 December 2019) occurrence, the Operator inspected and tested several landing gear/hydraulic system components as well as replacing the engine-driven hydraulic pumps and flushing the hydraulic system. Furthermore, the Operator reported that several flights had been subsequently flown and that the landing gear and its indication system had operated normally. In addition, a repeat inspection of the hydraulic filters was performed, as required, on 21 December 2021 with no adverse findings noted. New filter elements were installed at this time. Therefore, while it cannot be conclusive, the Investigation considers that the event on 12 January 2022 was likely not related to the subject occurrence.

2.5 Summary

The Investigation reviewed several possible reasons for the nose landing gear down-lock latch assembly not being fully engaged after the landing gear had been selected to the DOWN (extend) position on the 2 December 2019 flight from EIKY to EINN. The Investigation considers that free play in the nose landing gear down-lock latch assembly combined with anomalies within the *powerpak* and/or air in the hydraulic system were the most likely technical factors in the occurrence.

Regarding Human Factors, the flickering of the nose landing gear down indication light on the previous flight, prior to a successful landing, may have adversely affected the Pilot's trust in the landing gear indication system.

3. CONCLUSIONS

3.1 Findings

1. The Airworthiness Certification for the aircraft was valid.

2. The Pilot's Licence and Medical Certificate were valid for the flight being undertaken.

3. The flight from EINN to EIKY was the aircraft's first flight following the completion of extensive maintenance activity on the aircraft.

4. Maintenance personnel removed and refitted the bulb in the nose landing gear down indication light assembly during troubleshooting for an alternator fault carried out before the flight to EIKY.

5. The Pilot reported that when the aircraft was on the approach to EIKY, during the flight conducted immediately prior to the occurrence flight, the nose landing gear indication light was flickering, prior to coming on steady. This was followed by a normal landing at EIKY.

6. Before operating the aircraft on the return flight to EINN, the Operator was not informed that the nose landing gear indication light was flickering during the approach to EIKY.

7. The Pilot reported that when the aircraft was on the approach to EINN on the occurrence flight, the nose landing gear indication light was flickering. The Pilot did not recall if the light came on steady prior to the landing.

8. The nose landing gear collapsed when the nose of the aircraft was lowered during the landing on RWY 24 at EINN.

9. As a result of contact with the runway surface, the tips of both propellers were bent rearwards and the lower surface of the aircraft's nose section sustained abrasion damage.

10. The soldered joints between the electrical wiring and the bulb fitting were found to be in poor condition when the nose landing gear down indication light assembly was removed from the aircraft following the occurrence.

11. Significant free play was found in the nose landing gear down-lock latch hook pivot.

12. System testing identified that when the landing gear selector lever was selected to the DOWN (extend) position, the pressure in the down line was not maintained in accordance with Service Manual limits.

13. During workshop examination, the release detent screws on the *powerpak* for both the landing gear selector lever and the flap selector lever were found to have been unscrewed by approximately half an inch.

14. The landing gear selector lever did not return to the neutral position during system testing when the landing gear was selected to the UP (retract) position and the gear had fully retracted.

15. On 12 January 2022, the nose landing gear would not retract following a take-off from EINN. While it cannot be conclusive, the Investigation considers that this event was not related to the 2 December 2019 occurrence.

3.2 Probable Cause

The nose landing gear was not locked in the down position at the time of landing.

3.3 Contributory Cause(s)

1. Free play in the nose landing gear down-lock latch hook pivot, combined with anomalies within the *powerpak* and/or air in the hydraulic system, were the most likely technical factors in the occurrence.

2. The flickering of the nose landing gear down indication light on the previous flight, prior to a successful landing, may have adversely affected the Pilot's trust in the landing gear indication system.

3. The flickering of the nose landing gear down indication light on the previous flight was not reported to the Operator prior to the occurrence flight.

4. SAFETY RECOMMENDATIONS

This Report does not sustain any Safety Recommendations.

- END -

In accordance with Annex 13 to the Convention on International Civil Aviation, Regulation (EU) No. 996/2010, and Statutory Instrument No. 460 of 2009, Air Navigation (Notification and Investigation of Accidents, Serious Incidents and Incidents) Regulation, 2009, the sole purpose of this investigation is to prevent aviation accidents and serious incidents. It is not the purpose of any such investigation and the associated investigation report to apportion blame or liability.

A safety recommendation shall in no case create a presumption of blame or liability for an occurrence.

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