Australian Government
Civil Aviation Safety Authority

AIRWORTHINESS BULLETIN

Cessna 400 Series Electro-Hydraulic Undercarriage Systems

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1. Applicability

Cessna 400 series aircraft with electrically controlled, hydraulically operated (electro-hydraulic) undercarriage systems.

2. Purpose

To identify undercarriage system failures and to provide guidance to operators and maintainers to better ensure the intended reliability of the landing gear and the actuating system.

3. Background

A series of recent Cessna 400 electro-hydraulic undercarriage system failure reports has prompted an investigation into the history of defects for this system, using the CASA SDR database. This investigation revealed that not only has there been a recent increase in the rate of failures, but also that, in some cases, the same type of defect has been repeated for the same aircraft within a short period of time - but on the corresponding component in the same system on the other side of the aircraft or in the nose gear area.

4. System description

The Cessna 400 electro-hydraulic undercarriage system is an ‘open centre’ design which uses electrical switching to control oil flow for undercarriage retraction and extension. An open centre design means that system hydraulic oil is continually circulating at a comparatively low idle pressure (approximately 50 psi) until the selector valve directs hydraulic oil to the actuators to operate the system.

The Cessna 400 hydraulic system uses engine driven hydraulic pumps which continually circulate oil throughout the control system when the loading valve is de-energized. On moving the cockpit selector to command undercarriage ‘up’ or ‘down’, the electrically actuated hydraulic control valve is energised and the system changes from ‘idle’ mode, to ‘power’ mode, and system pressure increases to raise or lower the undercarriage.

Normally, the actuating system is automatically switched off and the hydraulic system pumps return to idle at the end of the landing gear retraction or extension cycle. If for some reason the system does not return to idle, the temperature of the hydraulic oil rises very rapidly and results in the hydraulic reservoir sight tube melting and liberating overheated system hydraulic oil into the nose baggage compartment, with resulting smoke in the cockpit. In one instance the hot oil also melted the pitot line to the captain’s airspeed indicator, which runs under the forward baggage compartment floor, directly under the reservoir.

5. Common Failures

The survey indicates that the more common undercarriage system failures can be grouped under the following headings.

Undercarriage Actuator

The main undercarriage actuator housing and ram shaft becomes a structural member, acting as the undercarriage side brace when the undercarriage is extended and locked in place. These actuators take significant loads during landing and are exposed to harsh operating conditions, particularly when operating from unpaved airstrips.

Typical failures include actuator housing ball end and failures in the threaded section, actuator ram shafts bending and actuator housings suffering external cracking. Water can also enter the actuator and cause corrosion of the locking mechanism and plunger, resulting in loss of locking function and undercarriage collapse. Severe internal corrosion can occur along the internal bore of the actuator, reducing the strength of the cylinder with similar results.

Actuator Mounted Switches and Plungers

The micro-switches mounted on the main landing gear actuators are operated by an internal plunger which moves to actuate the contacts in the micro-switch via the internal locking collar/piston device, inside the actuator. Plungers can develop limited movement (become stuck) in the down and locked position, due to wear or being corroded in the down and locked position.

Plungers wear during normal use. If the micro-switch is adjusted to take excess plunger wear condition into account, it is possible that vibration and internal wear and tear of the plunger and micro-switch can combine to give a range of false indications.

Since the main landing gear down switches are actuated by the plunger contacting the actuator down lock, a green light in the cockpit may only indicate that the actuator has extended. However, if the rod end fails and detaches from the undercarriage, the actuator may extend and indicate down and locked, but the undercarriage leg, not being attached to the actuator, will be unsafe and collapse on landing.

Undercarriage Actuator Locking

Actuator down locking is achieved by an internal locking ring which is spring loaded to the locked position. On selecting gear up, hydraulic system pressure initially acts on the piston to move the locking ring into the unlocked position, permitting the actuator to begin the retraction cycle. When the actuator is extended, the locking ring can malfunction due to wear and tear and corrosion, and lose its full locking function and allow the gear to collapse on landing, even though a green down and locked indication is present in the cockpit.

Undercarriage Wiring

Wiring associated with the undercarriage in the wheel wells is liable to fatigue and chaffing plus the effects of ageing from the normal undercarriage cycles and damage from the stones and debris thrown up by the wheels. The wiring and connections should be closely inspected for such defects.

Hydraulic Reservoir Sight 'Glass'

The sight 'glass' in the undercarriage system hydraulic reservoir is a plastic tube showing the level of the oil in the reservoir. In-flight failures of the sight tube are usually due to the plastic tube melting due to contact with overheated hydraulic system hydraulic oil. When the plastic sight tube melts, it releases hydraulic system oil into the fuselage nose section and can be accompanied by reports of smoke in the cockpit.

Hydraulic system oil overheats when the undercarriage has not fully completed the 'up' cycle. Whenever the off-loading valve remains energised in the 'loaded' position, it causes the engine driven pumps to continue to pump oil at high pressure against the weight of the undercarriage and through small orifices in the system. This heats the oil very quickly, melting the hydraulic reservoir sight tube, liberating overheated system oil, with resulting smoke in the cockpit.

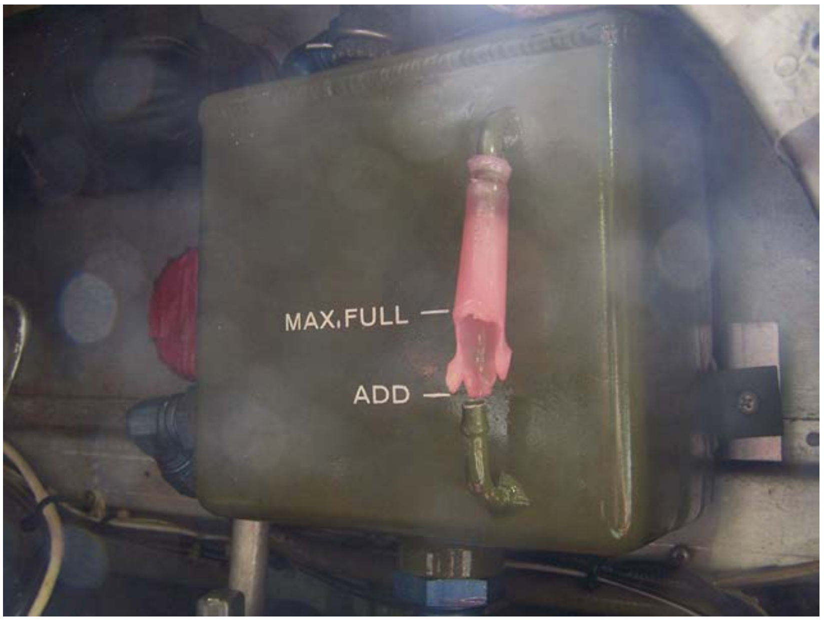

Fig. 1 Melted hydraulic reservoir sight tube.

It is for this reason that the Flight Manual requires the pilot to monitor the undercarriage amber ‘in-transit’ or hydraulic indicator light after take-off, and to lower the undercarriage and land if the amber light remains on for more than a few moments after selecting gear ‘up’ after take-off.

In one instance, following a double switch failure in the undercarriage retraction control and indicating system, the undercarriage did not complete the ‘up’ sequence and the ‘transit’ warning light malfunctioned. As a result the pilot was unable to be warned that the hydraulic system had not completed the undercarriage ‘up’ sequence and that the system hydraulic oil was overheating.

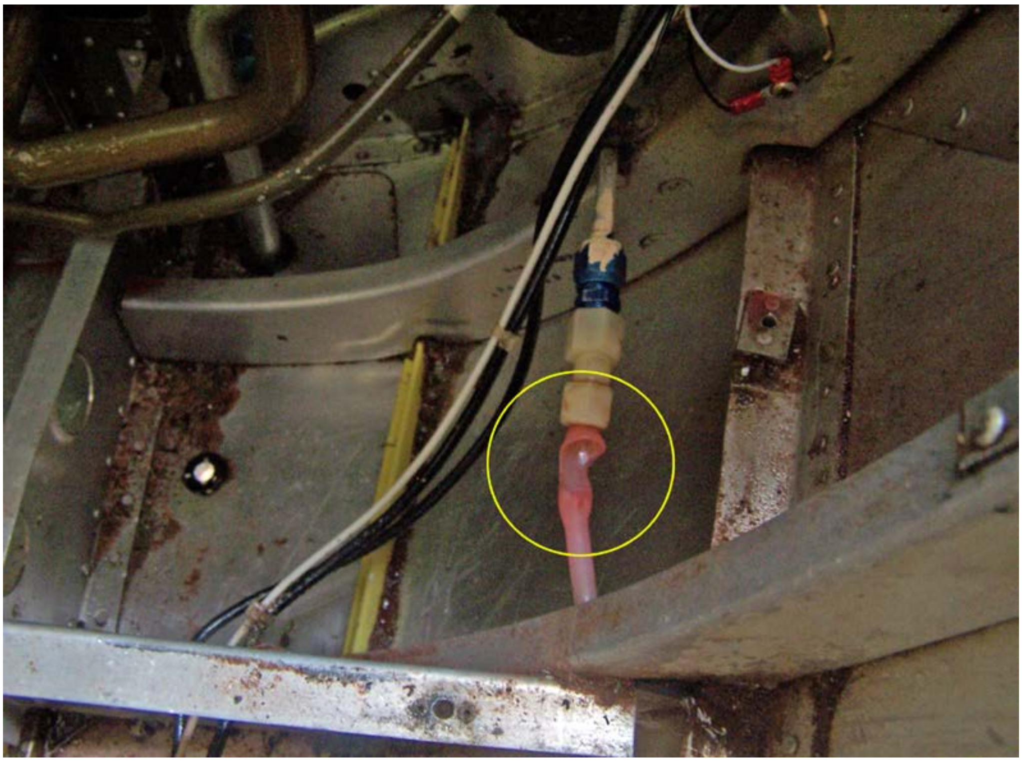

Fig. 2 Melted captain’s Pitot tube under the baggage compartment floor.

The hot oil not only melted the hydraulic reservoir sight tube, but the resulting hot oil released also melted the captain’s air speed indicator pitot line under the floor of the nose baggage compartment. This resulted in the the captain’s ASI displaying zero knots in-flight.

Hydraulic Lines

It is well known that the aluminium hydraulic lines in the fuselage, wings and wing leading edge area are prone to corrosion, chaffing and fatigue cracking.

Fig.3 Cracked hydraulic line.

Reports show that in some cases, internal corrosion pitting had developed into pin holes which developed into significant leaks. In addition, sections of aluminium piping have failed due to fatigue and chaffing. Such failures allow the undercarriage system hydraulic oil to be pumped overboard or into the wing cavity and allow the engine driven pumps to run dry, leading to possible pump failure and hydraulic system contamination.

As may be appreciated, the hydraulic system pipes experience continual pressure cycles and can suffer fatigue failure. Further, fatigue cracking in a hydraulic pipe or line on one side of the aircraft hydraulic system can be followed by the corresponding hydraulic line failing on the opposite side of the aircraft shortly afterwards, due to similarity in design and enduring similar pressure cycles.

The Cessna 400 Maintenance/Service Manuals require visual inspections of all of the plumbing in the system at regular intervals. In some cases there is also a requirement to pressure test the plumbing in the system to approximately 50% above the normal maximum system operating pressure, in order to reveal any potential weaknesses in the plumbing.

Actuator Ram Rod Ends and Actuator Ball Ends

The most common cause of Cessna 400 electro-hydraulic undercarriage system collapses is the failure of the main and nose gear actuator rod end. The rod ends typically suffer fatigue failure in the threaded section and on the sides of the rod end housing.

While rod end failures can occur on aeroplanes operating from paved runways, failures appear to be more prevalent with operations involving rough landing strips, which place additional high shock loading on the actuator rod ends.

Careful inspection for wear, cracks and corrosion in the rod end and actuator ball end can sometimes detect fatigue cracks before failure and prevent the undercarriage folding on landing roll. Again, as with aluminium hydraulic system pipe fatigue failures, if one actuator rod end fails due to fatigue, consider replacing all actuator rod ends, because they will have suffered similar cyclic loadings. Replacing only the failed rod end may prove costly in the longer term. Some operators not only inspect the rod ends periodically, they also retire rod ends on a regular basis.

Undercarriage Emergency Extension - Pneumatic system failures

Typical failures of the Cessna 400 electro-hydraulic emergency undercarriage deployment system and recommendations with regard to achieving increased reliability have been previously dealt with under CASA AWB 32-018 Emergency Undercarriage ‘Blow Down’ Systems.

5. Recommendations

Catastrophic in-flight failures of the hydraulic reservoir sight gauge due to system hydraulic oil overheating may be avoided by following the procedures in the aircraft Flight Manual.

CASA recommends that operators consider:

- Where an hydraulic pipe or actuator rod end fails on one ‘side’ of the system, consider also replacing the corresponding hydraulic pipe or actuator rod end on the other side of the system and establishing a retirement life for such items.
- Overhauling each undercarriage actuator and carry-out an approved MPI or retire the actuator rod ends approximately each 1500 hours or 1500 landing cycles unless otherwise specified by the manufacturer. This is particularly appropriate for those aircraft operating on rough airstrips.

- Include a periodic close inspection of the hydraulic system lines or pipes, particularly in the wing leading edges, wheel wells, etc. in accordance with applicable manufacturer's data.
- Advise and remind pilots to ensure they check/test the function of the aircraft annunciator panel as a part of their daily/pre-flight inspection.

6. Enquiries

Enquiries with regard to the content of this Airworthiness Bulletin should be made via the direct link e-mail address:

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