Australian Government
Australian Transport Safety Bureau

ATSB TRANSPORT SAFETY INVESTIGATION REPORT
Aviation Occurrence Investigation AO-2007-049
Preliminary

Fuel starvation – 102 km N Adelaide, SA
18 October 2007
VH-TMP
Cessna Aircraft Company C404

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Published by: Australian Transport Safety Bureau
Postal address: PO Box 967, Civic Square ACT 2608
Office location: 15 Mort Street, Canberra City, Australian Capital Territory
Telephone: 1800 621 372; from overseas + 61 2 6274 6440
Accident and incident notification: 1800 011 034 (24 hours)
Facsimile: 02 6247 3117; from overseas + 61 2 6247 3117
E-mail: atsbinfo@atsb.gov.au
Internet: www.atsb.gov.au

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Australian Transport Safety Bureau
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Abstract

On 18 October 2007, the pilot of a Cessna Aircraft Company C404 Titan aircraft was conducting a charter flight from Adelaide Airport, SA to Parafield Airport, Beverley airstrip, and return to Adelaide. The pilot had commenced descent into Adelaide on the final sector of the flight when the right engine lost power. There were no apparent anomalies and the fuel quantity gauges were showing adequate fuel in each tank. After securing the right engine, the pilot continued to Adelaide Airport and landed without further incident.

Aircraft maintenance engineers who inspected the aircraft reported that 3 L of fuel was drained from the right tank and 90 L was drained from the left tank. The fuel quantity gauge was indicating 150 lbs (95 L) in the right tank. An engineer found that one of the electrical circuits in the right fuel quantity indicating system had a high resistance. After wiring in the circuit was repaired, the fuel quantity gauge correctly indicated zero fuel in the right tank. Calibration of the fuel quantity indicating system was carried out and during that process, the left and right signal conditioners were found to be unreliable and were replaced or repaired.

The operator amended its fuel documentation and fuel planning procedures to include a secondary means of verification of fuel on board to cross-check the electric fuel indication system.

The investigation is continuing.

THE AUSTRALIAN TRANSPORT SAFETY BUREAU

The Australian Transport Safety Bureau (ATSB) is an operationally independent multi-modal bureau within the Australian Government Department of Transport and Regional Services. ATSB investigations are independent of regulatory, operator or other external bodies.

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

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

Purpose of safety investigations

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

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

Developing safety action

Central to the ATSB's investigation of transport safety matters is the early identification of safety issues in the transport environment. The ATSB prefers to encourage the relevant organisation(s) to proactively initiate safety action rather than release formal recommendations. However, depending on the level of risk associated with a safety issue and the extent of corrective action undertaken by the relevant organisation, a recommendation may be issued either during or at the end of an investigation.

The ATSB has decided that when safety recommendations are issued, they will focus on clearly describing the safety issue of concern, rather than providing instructions or opinions on the method of corrective action. As with equivalent overseas organisations, the ATSB has no power to implement its recommendations. It is a matter for the body to which an ATSB recommendation is directed (for example the relevant regulator in consultation with industry) to assess the costs and benefits of any particular means of addressing a safety issue.

About ATSB investigation reports: How investigation reports are organised and definitions of terms used in ATSB reports, such as safety factor, contributing safety factor and safety issue, are provided on the ATSB web site www.atsb.gov.au.

FACTUAL INFORMATION

Sequence of events

On 18 October 2007, the pilot of a Cessna Aircraft Company C404 Titan aircraft was conducting a charter flight from Adelaide Airport, SA to Parafield Airport, Beverley airstrip, and return to Adelaide. The pilot had commenced descent into Adelaide on the final sector of the flight when the right engine lost power. There were no apparent anomalies and the fuel quantity gauges were showing adequate fuel in each tank. After securing the right engine, the pilot continued to Adelaide Airport and landed without further incident.

The pilot recalled that during the pre-flight preparation of the aircraft at Adelaide, he noted that the fuel-remaining figure in the flight log from the previous day was 260 L (aviation gasoline) and that this matched the fuel quantity gauge readings of 200 lbs (127 L)[1] per side.

At about 0830 Central Standard Time[2], the pilot supervised the addition of 540 L of fuel to the aircraft. The pilot recorded in the flight log that 820 L (1,296 lbs) was the start fuel on board. The fuel quantity gauge indications for the left and right tank reflected the amount of fuel added and were similar.

At 0935, the pilot departed without passengers for the short flight to Parafield, where seven passengers embarked for the flight to Beverley airstrip, 280 NM (519 km) to the north. The pilot described the two sectors and the fuel quantity gauge indications specifically as normal. Engine shutdown was at about 1200.

At Beverley, the pilot recalled, the fuel quantity gauges were indicating total fuel of 750 lbs (475 L) with about 50 lbs (32 L) more indicated on one side than the other. Given the minimum fuel requirement, including reserves, for the flight to Adelaide was 640 lbs (405 L), the pilot considered that he had adequate fuel.

After about 25 minutes on the ground, the pilot departed Beverley airstrip with three passengers on board. The pilot climbed the aircraft to 9,000 ft and tracked via the flight planned route to Adelaide Airport. At about 1353 the pilot commenced descent.

The pilot recounted that the aircraft was passing 7,500 ft when the right engine surged and the aircraft yawed. A scan of the instruments showed that the right fuel flow needle was fluctuating, but all other indications were normal. Both fuel quantity indicators were ‘showing a bit over 200 lbs’ (127 L). The pilot turned on the auxiliary fuel pump and enrichened the mixture, but the engine did not respond.

About 15 to 20 seconds later, the engine stopped producing power. After checking the switches and controls the pilot secured the right engine which included

1 The conversions from pounds to litres of Avgas provided in this report are based on a fuel specific gravity of 0.72 and are rounded to the nearest litre. The actual specific gravity of fuel will vary somewhat according to temperature.

2 The 24-hour clock is used in this report to describe the local time of day. Central Standard Time was Coordinated Universal Time (UTC) + 9.5 hours.

feathering the right propeller. The pilot retrieved the applicable checklist and reviewed his actions.

The pilot reported the engine shutdown to the approach controller and advised that he would continue the flight to Adelaide. He also briefed the passengers. The pilot explained to the investigation that he considered the availability of services at Adelaide and the proximity of Edinburgh and Parafield airports in his decision-making.

The pilot conducted a single engine approach and landing. The fuel quantity gauge continued to indicate 200 lbs in the right tank.

Recent events

On 16 October 2007, two days before the incident, the aircraft was operated by one of the operator's other pilots on a charter flight from Adelaide to the Challenger mine airstrip and return. Before the flight, the pilot refuelled the aircraft with 400 L and at Challenger the pilot added the contents of two 200 L drums, one to each tank of the aircraft.

After the incident on 18 October 2007, the pilot reported that the flight on 16 October had been normal and there were no apparent fuel gauge faults. He did, however, recall that at about the midpoint of the return flight to Adelaide, the indicated fuel quantities were different. Assuming that the engine fuel burns had been different, the pilot had 'cross-fed' fuel by operating both engines from the right tank for about 8 to 10 minutes. That brought the fuel quantity indications to within 50 lbs (32 L) of each other. The pilot completed the flight without incident.

On 17 October 2007, the day before the incident, the aircraft was used for a series of scheduled passenger flights between Adelaide and Kingscote. The pilot of the first flight reported that on the return sector to Adelaide the aircraft had a noticeable tendency to roll to the left and required right aileron trim input; it wasn't severe, the pilot recalled, but it wasn't normal.

On the ground at Adelaide, the pilot did another pre-flight inspection and confirmed that the flight controls and wing flaps were operating correctly. The fuel gauge indications appeared even and the indicated amounts tallied with the fuel logs. The pilot conducted another flight to Kingscote with no change to the non-normal aileron trim settings. As scheduled, the pilot handed over the aircraft to another pilot, and advised him of the anomaly.

The pilot who flew the aircraft on the next flight to Kingscote confirmed the left roll tendency. He tried different trim settings and checked that the flaps retracted evenly, but was not satisfied with the handling characteristics. The pilot notified the operator and after returning to Adelaide changed aircraft.

An aircraft maintenance engineer inspected the aircraft's flight control system and did not find any defects. The item had not been entered into the maintenance release so it did not require a sign-off.

Aircraft fuel system

The aircraft fuel system incorporated an integrally sealed (wet) tank in each wing outboard of the engine nacelles. Each tank had capacity for 643.5 L of usable fuel and 15 L unusable fuel.

The aircraft was equipped with an electrical capacitance-type fuel quantity indicating system that was compensated for specific gravity. Each wing tank contained three internally mounted probes, which were electrically connected to a signal conditioner located outside the tank in each wing. The signal conditioner was electrically connected to the fuel quantity gauge in the cockpit (Figure 1). The gauge, located in the upper right instrument panel, displayed each tank's quantity in 50 lb and 30 US Gallon units (Figure 2).

Figure 1: Aircraft instrument panel

Figure 2: Fuel quantity gauge

Post-incident examination of the aircraft

Draining of the fuel tanks yielded 3 L (5 lbs) of fuel from the right tank and 90 L (142 lbs) from the left tank. The fuel quantity gauge subsequently indicated 150 lbs (95 L) fuel in the right tank and zero in the left tank.

The right fuel quantity indicating system was inspected by a suitably qualified LAME[3], who found that one of the electrical circuits in the wiring loom between the signal conditioner and the fuel tank bulkhead had a high resistance. The main conductor in the circuit was the shielding braid of a wire in the loom. At each end of the circuit, the braid was electrically connected to a plug through a short wire that was soldered to the braid (Figure 3). The engineer found that the soldered connection between each solder-sleeve and the corresponding shielding braid had deteriorated and there were signs of arcing. Resoldering both joints resulted in the gauge indicating correctly. The left fuel quantity indicating system was also inspected and no defects were found in the wiring.

3 Licensed aircraft maintenance engineer.

Figure 3: Typical solder-sleeve connection

The maintenance organisation advised that the fuel quantity indicating system was calibrated in accordance with the aircraft's maintenance manual using a Barfield test box. During that process, the left signal conditioner was found to be producing incorrect indications and was replaced. The right signal conditioner did not provide consistent indications and was repaired. Subsequent calibration was successful and the aircraft was returned to service.

Applicable maintenance requirements

The aircraft was operated in the regular public transport category and was therefore classified as a class A aircraft. Such aircraft were required to be maintained in accordance with a system of maintenance approved by the Civil Aviation Safety Authority (CASA). The aircraft's system of maintenance specified that scheduled instrument maintenance was to be performed in accordance with the schedule in section 5 of the system of maintenance manual.

The instrument inspection schedule included the following preamble:

> The instrument systems and components detailed in this schedule shall be inspected or tested so as to ensure that the system or component remains serviceable for the period between inspections subject to normal operation, inservice maintenance and reporting. When carrying out an inspection, the Manufacturers Maintenance Manual & Service Bulletins should be referred to for the complete inspection and test procedures.

The instrument inspection schedule contained the following fuel system maintenance requirement: 'Fuel pressure and quantity indication systems.'

The maintenance controller reported that the aircraft manufacturer's maintenance schedules for the aircraft type did not include any requirements for periodic calibration of the fuel quantity indication system. There was also no requirement for periodic calibration of other instrument systems.

A CASA airworthiness directive, 'AD/Inst/9 Amdt 6', dated 8/2003, prescribed the periodic test requirements for instruments in IFR aircraft. An operator could elect to comply with requirement 1, which allowed testing of the altimeters only, or elect to comply with requirement 2, which prescribed the checking of all the instruments and instrument systems. The operator had opted to comply with requirement 1 of the AD.

According to the maintenance controller, compliance with requirement 1 of the AD and the absence of a fuel calibration check in the manufacturer's maintenance schedules or approved system of maintenance schedules meant that there was no legal requirement for a periodic fuel calibration. Notwithstanding, the maintenance controller continued to schedule calibration of the fuel quantity indicating system at 3-yearly intervals, consistent with previous versions of the AD.

Airworthiness Bulletin 02-023, *Maintenance Requirements for Aircraft Components and Equipment*, dated 27 June 2007, contained the following guidance:

> If the owner elects to follow the new option of the Directives then the aircraft maintenance schedule should include the requirements to maintain the additional equipment, if not, then the earlier option needs to be continued.

Maintenance history of the fuel quantity indicating system

The last recorded fuel quantity indicating system calibration was dated 18 May 2005. On that occasion the fuel quantity indicators were reported to be inaccurate and 'numerous wiring and terminal repaired or terminated'. The system components in the right wing were also inspected and cleaned. Calibration of the fuel quantity indicating system was carried out and recorded as satisfactory.

The following maintenance was carried out to the fuel quantity indicating system between the system calibration dated 18 May 2005 and the incident on 18 October 2007:

- 17 February 2006 (an aircraft logbook entry) - The right fuel quantity system was reported to be intermittently going to full scale. Trouble shooting was carried out including inspection of wiring and pins and transposition of fuel signal conditioners. The fault apparently cleared.

- 22 December 2006 (recorded maintenance) - The right fuel indication system was sticking and fluctuating – the system was checked and signal conditioners swapped but the fault apparently cleared and the system was found to be satisfactory.
- 12 October 2007 (last recorded maintenance) - The right fuel gauge was reported to be over-reading by 150 to 200 lb and to be intermittent. A suitably qualified LAME inspected the aircraft and conducted fault finding including swapping the signal conditioners for test purposes. The fault cleared and there were no further reports of fuel quantity indicating system defects.

Pilot information

The pilot reported that he held an airline transport pilot (aeroplane) licence and had total flying experience of 2,328 hours. That included 1,318 hours of multi-engine experience, of which 150 hours was on the Cessna 404 aircraft type. He had been flying for the operator for about a year.

Operator information

The aircraft operator provided instructions and procedures for flight crew and other operational personnel in an operations manual.

Part A of the operations manual included a sub-section titled Fuel Documentation, which contained the following statements:

> Any fuel added to company aircraft shall be recorded in the trip record sheet … in accordance with the procedures of this section.
>
> Fuel remaining, fuel added and fuel used shall be entered into the trip record sheet. At the completion of the day's flight, the total fuel used shall be divided by the aircraft flight time giving an average fuel consumption which shall be entered into the box provided on the trip record.

Another sub-section, titled Fuel Usage Records, contained the following statements:

> Flight crew members shall consistently check the fuel burns against the residual fuel figure for accuracy on every sector.
>
> Fuel on board via the aircraft gauge readings are to be checked by the flight crew prior to every departure by comparing the fuel quantity uplifted, as per the fuel docket/release note, to the quantity remaining at the end of the previous flight.

Part B of the operations manual included data and procedures specific to the Cessna 404 aircraft type. The procedures relating to fuel quantity consisted of a description of the minimum fuel requirements for fuel planning and a check of the main tank fuel quantity as part of the pre-flight or daily inspection.

The chief pilot explained that the Cessna 404 fuel tanks did not have any sight gauges or drip-stick type fuel quantity measurement devices, and that each fuel tank had to be almost full before fuel was visible in the fuel filler opening. As it was not economically feasible to regularly operate with full tanks, pilots relied on the fuel gauge readings before and after refuelling.

Guidance material

The Civil Aviation Safety Authority published Civil Aviation Advisory Publications (CAAPs) as preferred methods for complying with the Civil Aviation Regulations 1988. CAAP 234-1(1) *Guidelines for Aircraft Fuel Requirements* included the following information regarding fuel quantity cross-checking:

> Unless assured that the aircrafts tanks are completely full, or a totally reliable and accurately graduated dipstick, sight gauge, drip gauge or tank tab reading can be done, the pilot should endeavour to use the best available fuel quantity cross-check prior to starting. The cross-check should consist of establishing the fuel on board by at least two different methods, such as:
>
> 1. Check of visual readings (tab, dip, drip, sight gauges against electrical gauge readings); or
>
> 2. Having regard to previous readings, a check of electrical gauge or visual readings against fuel consumed indicator readings; or
>
> 3. After refuelling, and having regard to previous readings, a check of electrical gauge or visual readings against the refuelling installation readings; or
>
> 4. Where a series of flights is undertaken by the same pilot and refuelling is not carried out at intermediate stops, cross-checks may be made by checking the quantity gauge readings against computed fuel on board and/or fuel consumed indicator readings, provided the particular aircrafts fuel gauge system is known to be reliable.

Airworthiness Bulletin 28-002, *Fuel quantity measurement and verification*, dated 15 May 2006, included the same information.

Related occurrences investigated by the ATSB

ATSB investigation number 200504768

At 1910 Eastern Standard Time on 23 September 2005, a Fairchild Industries Inc. Model SA227AC (Metro III) aircraft, registered VH-SEF, departed Thangool on a scheduled flight to Brisbane, Qld. There were two pilots and 16 passengers on board. Approaching overhead Gayndah, the L XFER PUMP (left fuel transfer pump) amber caution light illuminated, indicating low fuel quantity. The fuel quantity indicator showed substantial fuel in the tanks. The crew completed the checklist actions but the light remained on so they diverted the flight to Bundaberg. About 18 km from Bundaberg, the left engine stopped. The crew subsequently completed a single-engine landing at Bundaberg.

Four pounds (2 L)[4] of aviation turbine fuel was subsequently drained from the left tank, indicating that the left engine stopped because of fuel exhaustion. There was 49 lbs (28 L) fuel in the right tank, sufficient for about 10 minutes of cruise flight.

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4 The conversions from kilograms to litres of Avtur provided in this section of the report are based on a fuel specific gravity of 0.8 and are rounded to the nearest litre. The actual specific gravity of fuel will vary somewhat according to temperature.

Faults were found in a number of components of the fuel quantity indicating system. The maintenance manual procedures for calibration of the fuel quantity indicating system had not been followed correctly on two occasions in the previous 10 days. The result was that the fuel quantity indicating system was over-reading.

The crew relied on the fuel quantity indicator to determine the quantity of fuel on the aircraft before the flight. That practice was common to most of the operator's crews. The fuel quantity management procedures and practices within the company did not ensure validation of the aircraft's fuel quantity indicator reading. There was also no system in place to track the aircraft's fuel status during and after maintenance.

Following the occurrence, the operator developed new procedures for fuel quantity management and the Civil Aviation Safety Authority made rule changes regarding fuel quantity measurement and verification for transport category aircraft.

The final report is available from the ATSB website www.atsb.gov.au

ATSB investigation number AO-2007-017

On 26 June 2007 at 0639 Western Standard Time, an Empresa Brasileira de Aeronáutica S.A., EMB-120ER aircraft, registered VH-XUE, departed Perth, WA, on a contracted charter flight to Jundee Airstrip, WA. There were two pilots, one cabin attendant, and 28 passengers on the aircraft. The co-pilot was the handling pilot for the flight.

When the aircraft was on final approach to runway 08 at Jundee, it diverged to the left of the centreline and slowly rolled to the left. When the crew initiated a go-around at about 300 ft above runway elevation, the aircraft yawed and rolled left 'aggressively'. The aircraft veered left from a heading of about 070 degrees to about 190 degrees and descended to an estimated 100 ft above ground level. Together, the pilots were able to steady the aircraft's flight path. The wing flaps and landing gear were retracted.

Both pilots reported that during their efforts to regain control of the aircraft there were indications of a left engine failure. The crew completed the checklist actions for an engine failure in flight after which there was a significant improvement in aircraft performance. The crew diverted to Wiluna and landed without further incident.

The crew reported that, at the time of the power loss, the fuel gauges were indicating just over 200 kg (250 L) of aviation turbine fuel per side.

Aircraft maintenance engineers who later examined the aircraft reported that the left cockpit fuel quantity gauge displayed 300 kg (375 L) and the right gauge displayed 150 kg (188 L). A physical check revealed that the left tank contained no fuel, and the right tank contained 150 kg (188 L) fuel. Further examination revealed a fault in the outboard-most fuel quantity measurement probe from the left tank.

The operator amended its fuel quantity management procedures and the Civil Aviation Safety Authority issued a series of directions to the operator. The

Australian Transport Safety Bureau (ATSB) issued AO-2007-017-Safety Advisory Notice-013:

> The ATSB suggests that all turboprop operators take note of the following safety issue and review their processes accordingly:
>
> The processes used by some turboprop operators for checking the fuel quantity on board prior to flight have not used two methods of sufficient independence. In particular, the practice of using a comparison of a gauge indication after refuelling with the gauge indication prior to refuelling plus the fuel added is not adequate to detect gradually developing errors in gauge indications.

The investigation is continuing. The preliminary report is available from the ATSB website www.atsb.gov.au

Further investigation

The investigation is continuing and will be considering the following:

- Factors regarding the fuel loss from the right tank
- Efficacy of the operator's safety management system
- Adequacy of Requirement 1 of AD/Inst/9 Amdt 6 in relation to aircraft operated on scheduled passenger carrying or charter flights
- Adequacy of fuel quantity measurement guidance in CAAP 234-1(1) *Guidelines for Aircraft Fuel Requirements* and Airworthiness Bulletin 28-002, dated 15 May 2006
- Efficacy of CASA approval processes for fuel quantity measurement and instrument maintenance procedures of RPT operators.

SAFETY ACTIONS

Operator

On 22 October 2007, the aircraft operator issued a memo to all pilots to direct that all fuel dockets/receipts be retained and filed. Pilots were also reminded that the fuel added on the trip card should reflect the fuel on the receipt and that accuracy was required in completion of the trip card and maintenance release.

The operator made a sight gauge for the Cessna 404 by attaching a fitting to a clear plastic hose to allow connection of one end to the inboard fuel drain of either fuel tank. As known amounts of fuel were added, marks were added to each engine nacelle to indicate various fuel levels.

The operator also amended its operations manual, effective from 1 November 2007. In Part A, the Fuel Documentation sub-section was expanded with the following text:

> Fuel dockets/receipts shall be checked by the Pilot in Command who shall ensure that the documentation reflects the quantity and grade of fuel delivered to the aircraft. The Pilot in Command is also responsible to ensure that the correct quality control measures have been certified on the delivery docket and is retained/returned to the main base for retention.
>
> In addition the pilot in command shall ensure that a secondary means of verification of fuel on board has been used to cross check the electric fuel indication system as per CAR 215 direction instrument no. WRA3130 appendix 12 (refer Part B of applicable aircraft).

In Part B of the operations manual, the following text was added to the Cessna 404 fuel planning procedures:

> Secondary verification of fuel is required prior to departure and after every refuel in the C404. The minimum fuel load for all operations shall be 300 lts. Visual verification of 300 lts can be achieved by using the visual site tubing located in the right hand wing locker.
>
> PROCEDURE: press rubber ended valve on to under wing fuel drain, outboard of engine cowl, while holding open end above wing and against fuel markings on cowl to achieve a reading when fuel has stabilised in the tube. NOTE confirmation via Turn and Bank co-ordinator that the aircraft is on level ground and wings level is required prior [to] procedure.
>
> If a discrepancy exists, of greater than 20 lts between the anticipated end fuel load, after refuelling (that is the end figure from the previous flight and the fuel added) a special occurrence report will be submitted to the chief pilot for investigation.

Similar text was added to the fuel planning procedures applicable to the operator's other aircraft.

Civil Aviation Safety Authority

The Australian Transport Safety Bureau briefed Civil Aviation Safety Authority (CASA) personnel on the circumstances of the occurrence. CASA advised that:

- A Civil Aviation Regulation (CAR) 215 direction [WRA3130] had been issued to the operator to ensure that a secondary means of verification of fuel on board was used to cross check the electric fuel indication system.

The Civil Aviation Safety Authority is also considering:

- Advising Air Safety Auditors of the circumstances of the incident and the need for operators to have fuel quantity measurement procedures that provide a high level of assurance that the required fuel is actually on board an aircraft
- Reviewing the information in Civil Aviation Advisory Publication 234-1(1) *Guidelines for Aircraft Fuel Requirements* that refers to fuel quantity cross-checking
- The removal of Airworthiness Bulletin 28-002 *Fuel quantity measurement and verification*.