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Cross-Control Upset

The Metro's autopilot was engaged when the pilots induced a sideslip to balance fuel. When the autopilot reached its control limits and disengaged, the aircraft rolled and entered a spiral dive.

BY MARK LACAGNINA

Last year's upset and in-flight breakup of a Fairchild Metro III in New Zealand has prompted investigators to call for the development of a standard procedure for balancing fuel in the aircraft while in flight and for a warning that the autopilot must be disengaged during the procedure. The Metro's flight crew was using rudder trim to place the aircraft in a sideslip while balancing fuel in the wing tanks and lost control when the autopilot disengaged and the aircraft abruptly rolled and dived.

The fatal accident occurred during a scheduled cargo flight from Auckland to Blenheim the night of May 3, 2005. In its final report, the New Zealand Transport Accident Investigation Commission (TAIC) said that the upset probably would not have occurred if the crew had hand-flown the aircraft while balancing the fuel.

The aircraft was scheduled to depart at 2100 local time, but the loading of the cargo was not completed until 2115. The flight crew then ordered about 1,000 lb (454 kg) of additional fuel and told the fueler to put all of it into the left wing tank. "This was probably to expedite their departure after the delayed loading," the report said. The crew took action to balance the fuel, and the wing tanks likely were within the 200-lb (91-kg) maximum differential specified by the aircraft flight manual (AFM) for takeoff.

The aircraft departed from Auckland at 2136. The captain, 43, had 6,500 flight hours, including 2,750 flight hours in type, and was a Metro line-training captain for the operator, Airwork (NZ) Limited. The first officer, the pilot flying (PF), 41, had 2,345 flight hours, including 70 flight hours in type. Both pilots held Metro type ratings. They had flown together once previously, five days before the accident flight. "The operator's records showed that both pilots had been trained in autopilot use and in fuel-transfer procedures," the report said.

The crew flew the aircraft to Flight Level (FL) 180 (approximately 18,000 ft), where they likely encountered instrument meteorological conditions and moderate turbulence. The crew requested, and received, clearance to climb to

FL 220. After reaching that flight level, the crew maintained climb power for about 15 minutes to make up some of the delay in departure. The report said that the aircraft likely was above the clouds and in smooth air at FL 220.

Unpublished Technique

The Metro's fuel system comprises two wing tanks that supply fuel to their respective engines. The tanks are connected by a crossflow tube containing a valve that can be opened to balance fuel between the tanks or, if one engine is inoperative, to make the fuel in both tanks available to the operative engine. "The gravity-crossflow fuel system was unusual and probably confined to the SA 226/227 [Merlin/Metro] family of aircraft," the report said. "Other types had either a pumped crossfeed system or a pumped crossflow system."

Annunciator lights indicate when the crossflow-valve switch is selected to "OPEN" and when the crossflow valve is not fully closed. Several checklists, including the "Before Starting Engines" and the "Before Takeoff" checklists, require the crossflow valve to be closed.

Airwork told investigators that it believed a fuel imbalance was unlikely to develop during a typical flight duration with both engines operating normally and with the crossflow valve closed. However, other Metro operators said that they had observed fuel imbalances as great as 120 lb (54 kg) per hour "between engines that were at the opposite ends of the overhaul period." The overhaul period for the Metro III's Honeywell TPE331 engines is 7,000 hours. The left engine on the accident aircraft had accumulated 710 hours since its last overhaul; the right engine had accumulated 3,491 hours since overhaul.

Airwork did not have a written procedure for balancing fuel, and the AFM provided no detailed procedure, the report said.

"The operator's usual but unpublished technique to balance the fuel in flight, if necessary, was to open the crossflow valve and fly with the fuller wing held just higher than wings-level attitude," the report said. "Slight opposite rudder, or 'cross-control,' was necessary to maintain the desired heading. The operator considered that this method was adequate and balanced the fuel quickly. Information obtained from pilots with Metro experience with several operators confirmed that this method was used [and that] it required minimal rudder-control input and was efficient. Some pilots reported that they would apply a small amount of rudder trim while the aircraft was flying on autopilot to achieve this."

After the crew completed the "Cruise" checklist about 2212, the captain decided to transfer fuel from the left wing tank to the right wing tank. "There was no evidence of how much imbalance he was responding to," the report said. The imbalance likely resulted from the asymmetric fueling rather than a difference in the engines' fuel consumption. "The engine with the longer time since overhaul was still only halfway through the overhaul period, and the flight time since [the aircraft] left Auckland was probably insufficient to develop much fuel imbalance," the report said. "The imbalance may have been within AFM limits [200 lb] for the upcoming landing but was sufficient for the captain to want to tidy up while the aircraft was in cruise."

The captain told the first officer, "We'll just open the crossflow [valve] again. … Sit on left ball and trim it accordingly." The report said that the captain then clarified the instruction: "Step on the left pedal and just trim it to take the pressure off," he said. "Get the ball out to the right as far as you can … and just trim it."

The first officer said, "I was being a bit cautious." The report said that this comment likely indicated that the first officer was concerned that the rudder input commanded by the captain was excessive.

"Don't be cautious, mate," the captain said. "It'll do it good."

The first officer asked, "How's that?" The captain replied, "That's good. Should come right. Hopefully, it's coming right."

'You'd Better Grab It'

The report said that the autopilot likely was maintaining the selected altitude and the selected heading or course. "When left rudder was applied, the aircraft would have yawed left and tried to roll left as a result of normal aerodynamic yaw/roll coupling," the report said. "The autopilot would have applied right aileron control to counter this rolling tendency and would also have tried to maintain the heading (or course) by applying more right aileron so that the aircraft flew right-wing-down in a straight sideslip to the right."

The crew did not increase power from the cruise setting, and airspeed began to decrease. Air traffic control (ATC) radar data and flight data recorder (FDR) data indicated that the aircraft began a gradual left turn. The turn rate then increased, and the aircraft began to descend.

The captain said, "Doesn't like that one, mate. You'd better grab it." The aircraft's ground-proximity warning system (GPWS) then generated an aural "bank angle" warning. The report said that this warning is provided when bank angle exceeds 40 degrees and is repeated every three seconds until bank angle decreases below 40 degrees.

Soon after the first "bank angle" warning, the cockpit voice recorder (CVR) recorded a chime, which probably indicated a deviation from the selected altitude, the report said. During the next 23 seconds, the CVR recorded seven more "bank angle" warnings.

New Zealand Transport Accident Investigation Commission

"The probable explanation for the bank angle excursion and the altitude loss is that the autopilot had disengaged automatically as a result of a servo reaching its torque limit," the report said. "With the autopilot constraint removed, the aircraft abruptly responded to the trimmed rudder input by rolling left and starting to yaw its nose down into a steeply banked diving attitude."

The captain asked the first officer to confirm that the autopilot was disengaged. Soon after the first officer confirmed that the autopilot was disengaged at 2213, the CVR recording ended. ATC radar contact was lost a few seconds later, as the aircraft descended through 19,900 ft.

Airspeed and wing loading increased rapidly. Twelve seconds after the captain told the first officer to "grab it" — take manual control of the aircraft — maximum operating airspeed, 227 kt, was exceeded. Wing loading increased beyond the limit load of +3.02 g, or 3.02 times standard gravitational acceleration.

"Over the last 20 seconds of recorded data, the airspeed increased from 175 [kt] to almost 300 kt, the vertical acceleration increased from about +1.5 g to +4.2 g," the report said. "These data characterize a rapidly developing spiral dive."

Trim Likely Thwarted Recovery

The left-rudder trim that had been applied to balance the fuel likely contributed to the crew's inability to regain control of the aircraft. "The FDR did not record control positions, so it is not possible to determine exactly what the crew did to try to return the aircraft to a normal attitude," the report said. "The normal recovery action sequence for a spiral dive is:

- "Reduce power to minimize airspeed increase;
- "Roll the aircraft to wings-level; then,
- "Pitch the aircraft up to the horizon."

The report said, "This action needs to be taken promptly, positively and smoothly, and in that order, so that flight-envelope limitations are not exceeded."

The CVR recorded the sounds of power reduction about seven seconds before the recording ceased. "This was late in the development of the spiral dive, and the delay would have exacerbated the situation," the report said.

Compression buckling in both wings indicated that the crew applied substantial right-wing-down aileron-control input. "This indicated that appropriate control input was being made to try to roll the aircraft to the right, towards wings-level, as the aircraft wing structure became loaded towards failure," the report said. "The reason why the applied right aileron control was not effective in rolling the aircraft towards wings-level was not conclusively determined, but it was likely to have been a direct result of the left rudder trim which had been applied, and which probably remained applied throughout."

Increasing aerodynamic loads recorded by the FDR indicated that substantial up-elevator control input also was applied. "This elevator input would have been ineffective in pitching the aircraft up towards the horizon, however, because of the steeply banked attitude," the report said. "It could only have further tightened the turn, escalating the spiral dive. The bank attitude needed to be reduced towards wings-level before the elevator control could raise the nose of the aircraft."

The report said that a fire erupted when both wings folded upward and separated from the aircraft. Several witnesses described an intense and unusual noise, and orange-yellow lights or fireballs falling through broken layers of cloud. The left wing was on fire as it fell. The flight deck, which had been struck by the left propeller when the wing folded, also separated in flight. Most of the wreckage was found at about 700 ft on hilly farmland 7.0 km (3.8 nm) northeast of Stratford, which is near the western coast of New Zealand's North Island.

Similar Events

The report cited an incident in Australia and a fatal accident in the United States in which fuel imbalances and upsets likely occurred in similar aircraft.

Fairchild SA-227AC Metro III

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Designer Edward J. Swearingen's Merlin corporate/business aircraft first flew in 1965 with Pratt & Whitney Canada PT6A-20 engines. All subsequent versions of the Merlin and its longer-fuselage, regional airline derivative, the Metro, have had Garrett, now Honeywell, TPE331 engines. The Metro III, introduced in 1981, has longer wings, a greater useful load and more powerful engines than the preceding Metro models.

The aircraft accommodates two pilots and 20 cabin occupants. Maximum takeoff weight is 14,500 lb (6,577 kg). Maximum fuel weight is 4,342 lb (1,970 kg). Maximum rates of climb are 2,370 fpm with two engines and 690 fpm with an engine out. Maximum cruise speed at 25,000 ft and at 12,500 lb (5,670 kg) is 263 kt. Stall speeds are 98 kt clean and 87 kt in landing configuration.

The Merlin/Metro series was produced by Swearingen Aircraft Co. and by Fairchild Aircraft Corp. Production was terminated in 1999.

Source: *Jane's All the World's Aircraft*

The incident involved a Fairchild Merlin III that was on a charter flight in New South Wales on Aug. 30, 2004.[1] The fuel systems in the Merlin and the Metro are essentially the same. The pilot said that after reaching cruise altitude, FL 160, he observed that the aircraft was in a slightly right-wing-low attitude. He used left-rudder trim to level the wings and engaged the autopilot. About 2.5 minutes later, the autopilot disengaged, and the aircraft rolled right and entered a spiral dive. The pilot regained control about 50 seconds later, at 5,200 ft. Neither he nor his seven passengers were injured. The pilot told investigators that, after regaining control, he noticed that the fuel gauges showed 772 lb (350 kg) more fuel in the right tank than in the left tank. The final report on the incident by the Australian Transport Safety Bureau said that the fuel imbalance likely occurred because the crossflow valve either was open when the flight began or was inadvertently opened during the flight.

The U.S. National Transportation Safety Board investigation of the Feb. 8, 2006, accident in Paris, Tennessee, was continuing at press time. A preliminary report said that during a cargo flight from Ohio to Texas at 16,000 ft, the pilot of a Swearingen Metro II conducted 360-degree turns to the left and right, and then requested radar vectors to the nearest airport.[2] After issuing a heading to the nearest airport, the air traffic controller asked the pilot if he had an emergency. The pilot replied that he had an asymmetric fuel condition. "About a minute later, the pilot transmitted 'mayday' six times, and shortly after this, radar and radio contact with the flight was lost," the preliminary report said. "The airplane was heard and then seen descending at a high rate of speed in a near-vertical attitude."

"The amount of control-wheel displacement by the autopilot would not have been readily apparent on a dark flight deck at night."

Tactile Feedback

The TAIC report said that by flying the aircraft with the autopilot engaged, the first officer received no tactile feedback of the control forces that were being applied during the sideslip maneuver.

"If the autopilot had not been engaged, the PF would have had to apply right aileron manually in coordination with the left rudder input to achieve the same result," the report said. "In manual flight, the PF would have received continuous tactile feedback from the controls to indicate the control forces and displacements he was producing, and would have had to monitor closely the aircraft attitude and heading on his instruments. With the autopilot engaged, and especially with the rudder trimmed out, he would not have had such feedback because the autopilot would have been holding the control forces generated, and the PF might not have perceived a need to monitor the aircraft's attitude closely.

"In addition, both pilots may have been monitoring the fuel gauges to observe the success or otherwise of the fuel transfer. The amount of control-wheel displacement by the autopilot would not have been readily apparent on a dark flight deck at night."

The report said that the absence of a written standard operating procedure (SOP) for balancing fuel with the Metro's — and Merlin's — gravity-crossflow system creates the potential for individual pilots to use different methods, including the "extreme sideslip" that the accident captain instructed the first officer to use.

"Written SOPs are the normal method for an operator to detail to crews how to perform common tasks," the report said. "This ensures that tasks are carried out in a safe and efficient manner, and that each crewmember knows what is required. While the fuel-balancing procedure might not be required on many flights, it clearly needed a written SOP. Because the gravity-crossflow system was specific to the Metro family of aircraft, the appropriate procedure was unlikely to fall within pilots' understanding of good aviation practice."

Based on these findings, the TAIC in February 2006 recommended that the New Zealand Civil Aviation Authority (CAA) work with the U.S. Federal Aviation Administration (FAA) to amend the AFMs of the Metro/Merlin family of aircraft "to include a limitation and caution that the autopilot and yaw damper must be disconnected while in-flight fuel balancing is done." TAIC also recommended that the CAA and FAA incorporate in the AFMs a procedure for in-flight fuel balancing.

In May 2006, the CAA replied that it accepted the recommendations and had begun correspondence with FAA on amending the AFMs. ●

This article is based on New Zealand Transport Accident Investigation Commission Aviation Occurrence Report 05-006: "Fairchild-Swearingen SA227-AC Metro III ZK-POA, Loss of Control and In-flight Break-up Near Stratford, Taranaki Province, 3 May 2005." The 44-page report contains illustrations.

Notes

1. Australian Transport Safety Bureau Aviation Safety Investigation Report 200403209.
2. U.S. National Transportation Safety Board preliminary report ATL06FA045.