National Transportation Safety Board

Washington, D.C. 20594

Safety Recommendation

Date: September 13, 2007

In reply refer to: A-07-52 through -54

Honorable Marion C. Blakey
Administrator
Federal Aviation Administration
Washington, D.C. 20591

On July 22, 2003, about 1015 Pacific daylight time, a Cessna Citation 525, N996JR, was ditched in the waters of Penn Cove, Coupeville, Washington, following a loss of elevator trim control[1] that resulted in an uncommanded nose-down pitch attitude. The commercial pilot and passenger were not injured. Tango Corporation of Minden, Nevada, operated the cross-country flight under the provisions of 14 *Code of Federal Regulations* (CFR) Part 91. Visual meteorological conditions prevailed for the flight, which was being operated on an instrument flight rules flight plan from the Victoria International Airport, Sidney, British Columbia, Canada, with a planned destination of Gowen Field, Boise, Idaho.[2]

According to the pilot's postaccident statement, he configured the airplane's autopilot for a climb to flight level 330, (33,000 feet) at an indicated airspeed of 200 knots, and a climb power setting shortly after departing Victoria International Airport about 0950. However, after climbing through 14,000 feet mean sea level, the pilot noticed a decrease in the airplane's rate of climb. In response, he pressed the autopilot/trim disengage switch on the control yoke, which disconnected the autopilot. The pilot indicated that the airplane's nose immediately pitched down to an attitude approximately 10º below the horizon and that "within seconds it was apparent that level flight was not possible" as he pulled back on the control yoke.

The pilot reported that he reduced engine power to idle then attempted to re-trim the airplane by commanding nose-up trim using the electric trim switch on the control yoke. He stated that the trim did not move, however. The pilot then noticed that the elevator trim indicator,

[1] The elevator and elevator trim systems provide longitudinal control of the airplane. The airplane's two elevators, one on the trailing edge of each side of the horizontal stabilizer, can be actuated mechanically (via movement of the control column and a series of cables, pulleys, pushrods, and quadrants) or electrically (via the autopilot elevator servo and interconnecting cables, which apply a force to the elevator cables and aft elevator quadrant). Elevator trim tabs, one connected to the trailing edge of each elevator, can also be moved mechanically (via movement of the trim control wheel and cables to the trim actuators) or electrically (by the pilot activating the elevator trim switch on the control yoke or by the autopilot when it is engaged).

[2] The brief for this accident, SEA03FA147, can be found on the National Transportation Safety Board's Web site at <http://www.ntsb.gov/ntsb/query.asp>.

mounted on the center pedestal next to the manual trim wheel and the pilot's right leg, was in the full-forward (nose-down) position. The pilot reported that he then attempted to manually trim the airplane but that he also had difficulty moving the manual trim wheel. He then asked the passenger, who was seated in the copilot seat, to help pull back on the control column. The pilot reported, however, that even with he and the passenger exerting what the pilot described as "maximum yoke back pressure," the airplane's negative, nose-down pitch attitude increased, airspeed approached the maximum operating speed (for operation at less than 30,000 feet) of 263 knots, and rate of descent increased to approximately 2,000 feet per minute. The pilot also stated that, because of the severe control forces required, he could not safely remove either hand from the control yoke for more than several seconds at a time to manipulate other flight deck controls.

Despite the nose-down force on the control column, the pilot was able to maneuver the airplane to the vicinity of Whidbey Island, Washington, and attempted to land the airplane at a nearby airport. After reaching the island, however, the pilot determined he could not safely land the airplane on a runway and elected to land on the water at Penn Cove.[3] He indicated that he extended the flaps to a landing position and, with the landing gear retracted, ditched the airplane into the water, coming to rest approximately 300 yards from shore.

Postaccident examination and testing of the pitch trim printed circuit board (PCB),[4] part number 6518351-5, serial number 0154, determined that the autopilot trim down (or K6) relay,[5] failed in the closed, or power on, position. As a result, power was continuously applied to the electric trim motor[6] and clutch, which drove and held the elevator trim tabs to their full nose-down position. Further examination of the elevator trim system revealed that the autopilot/trim disengage switch, which the accident pilot pressed in response to the decrease in the airplane's climb rate, would not have disengaged the electric trim motor during the type of failure experienced in the accident airplane. The investigation concluded that the K6 relay failure constituted a single-point failure in the Cessna Citation 525 electric pitch trim system.

The probable cause of this accident was determined to be "the loss of airplane pitch control (trim runaway and mistrim condition) resulting from a failure in the airplane's electric pitch trim system. Factors that contributed to the accident were the manufacturer's inadequate design of the pitch trim circuitry that allowed for a single-point failure mode and the absence of an adequate failure warning system to clearly alert the pilot to the pitch trim runaway condition in sufficient time to respond in accordance with the manufacturer's checklist instructions."[7]

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[3] Penn Cove, Washington, is located on Whidbey Island.

[4] The PCB acts as a control interface between the elevator trim switch and the electric trim motor.

[5] The K6 relay responds to commands from the autopilot and sends power to the electric trim motor and clutch, which then move the elevator trim tabs in the airplane nose-down direction.

[6] The electric trim motor moves the tabs at a rate of approximately 0.5º per second.

[7] The Cessna Citation 525 abnormal procedures checklist for an electric elevator trim runaway calls for the pilot to pull the pitch trim circuit breaker to "permanently remove power to the trim motor before releasing the autopilot/trim disengage switch." Once power is removed from the electric trim motor, the pilot is able to rotate the trim wheel and manually reconfigure the elevator trim tabs. The accident pilot disconnected the autopilot before identifying the trim runaway condition or executing the Electric Elevator Trim Runaway checklist.

Although Cessna eliminated the failure mode that led to the runaway condition,[8] the lack of a clear warning for a trim runaway condition remains unaddressed. The investigation also identified control forces associated with trim position in Cessna Citation 525s and the difficulty of quickly isolating and pulling the pitch trim circuit breaker in response to an elevator trim runaway as additional concerns.

Pilot Recognition of an Elevator Trim Runaway Condition in Cessna Citation 525s

Because the Cessna Citation 525 is not equipped with a clear indication or warning for an electric elevator trim runaway (such as an aural or visual trim-in-motion warning), the accident pilot had only indirect indications to assist in identifying the condition, and these indications were insufficient to allow timely recognition of the problem. For example, the tactile indications of increasing pitch control force (which was a result of elevator movement commanded by the autopilot to compensate for the K6 relay failure) were not immediately evident to the pilot because the airplane was in autopilot mode rather than being flown by hand. The accident pilot also might have identified the runaway pitch trim condition sooner by noting the continuous nose-down motion of the trim wheel or the elevator trim position indicator before it reached the full-forward position. However, detecting an undesirable motion of the trim wheel and indicator would require the pilot to actively monitor these controls over an extended period of time, which would require directing attention downward to the center pedestal and away from critical flight indications.

In addition, although a pilot can identify trim inputs based on the trim wheel's motion, the wheel's relatively slow rotational speed[9] may be inconspicuous to a pilot whose attention is focused on other tasks. The trim wheel's design may also impede recognition of trim inputs. For example, the trim wheel is a solid dark color that would make it difficult to discern the movement of the trim tab position indicator, which is located immediately adjacent to and moves in conjunction with the trim wheel. Trim wheel motion is not augmented with an aural identifier, such as a clacker.

The National Transportation Safety Board is aware that the Citation 525 autopilot system alerts a pilot to a pitch mistrim[10] condition by illuminating the AP OUT OF TRIM light directly above the altimeter; however, it does so only after the autopilot compensation reaches a prescribed threshold and is not accompanied by an aural indication. Cessna recommends that pilots perform the AP Out of Trim checklist when presented with the AP OUT OF TRIM light. However, this checklist does not direct the pilot to pull the pitch trim circuit breaker, which is the appropriate action to arrest a pitch trim runaway as instructed in the Electric Trim Runaway

[8] On December 9, 2003, Cessna issued Service Bulletin 525-27-17, which modified the affected electric pitch trim system to ensure that no single electrical fault could cause uncommanded motion of the electric pitch trim system and modified the electric elevator trim disconnect protection to ensure that the autopilot/trim disengage switch would stop the electric trim. The FAA issued Airworthiness Directive AD 2004-14-20, effective August 23, 2004, requiring this modification.

[9] The Citation 525 autopilot moves the trim wheel at a rate of 1 revolution approximately every 12 to 17 seconds.

[10] A mistrim condition in autopilot mode can result from a number of causes other than a trim tab runaway, such as a jam or loss of power to the trim tab motor.

checklist. If the AP OUT OF TRIM light is illuminated because of a pitch trim runaway, a pilot could complete the recommended checklist without correcting the problem and would have to transition to the Electric Elevator Trim Runaway checklist to be prompted to pull the pitch trim circuit breaker. The accident pilot reported that he did not observe the trim wheel motion or the AP OUT OF TRIM indication before he disconnected the autopilot.

Advisory Circular (AC) 23-8, "Flight Test Guide for Certification of Part 23 Airplanes,"[11] provides guidance for demonstrating compliance with trim system design and construction regulations, specifically as related to reliable trim runaway warning systems. The guidance indicates that "pilot recognition time is considered negligible" in airplanes equipped with trim-in-motion systems[12] because they provide the pilot with a clear warning of trim runaway conditions. Without a trim-in-motion system, a pilot's recognition time should not be considered negligible and must be added to the response time delay established in the same flight test guidance material[13] unless demonstrated to be otherwise acceptable to the Federal Aviation Administration (FAA) in flight tests. AC 23-8 also indicates that the flight control forces experienced by the pilot must not exceed those defined in 14 CFR 23.143(c)[14] during the time period prescribed for recognition and response.

The Safety Board notes that many transport- and commuter-category aircraft[15] are equipped with trim-in-motion systems even though two pilots are required to operate the aircraft. Some single- and multiengine airplanes certified under 14 CFR Part 23 for single- and dual-pilot operation (though not as many as the transport-category class) have also been equipped with trim-in-motion systems, frequently when an autopilot system is installed. However, the Cessna Citation 525 airplane design was certified without a trim-in-motion system.

The Safety Board is concerned that, when the Citation 525 is in autopilot mode, the available cues for an electric elevator trim runaway, such as trim wheel motion or an out-of-trim light, do not provide pilots with a salient and reliable means to detect this unsafe condition in a timely manner. Because the airplane is certified for single-pilot operation, it is critical to alert a pilot to a trim runaway condition before the associated control forces exceed what a single pilot can manage, as was the case with the pilot involved in the Penn Cove accident. Timely pilot recognition of a pitch trim runaway and execution of the Electric Elevator Trim Runaway checklist can increase the likelihood that pitch control can be restored. Therefore, the Safety

[11] Revision A of AC 23-8 was in effect at the time the Cessna Citation 525 airplane was certified. Paragraph 139.c.(4) of Chapter 3 specifically deals with trim runaway conditions and evaluating compliance with the related regulations contained in 14 CFR 23.677.

[12] The term "trim-in-motion system" is a general description of a system that is intended to clearly alert the pilot when pitch trim automation is active, when that activity is sustained for a particular period of time, or when the trim control surface has completed a particular range of motion.

[13] Paragraphs 130.c (4)(i) and (ii) in Chapter 3 of AC 23-8 define acceptable response time delays as 1 second for the takeoff, approach, and landing phases of flight and 3 seconds for the climb, cruise, and descent phases of flight.

[14] Regarding maximum pitch control forces, 14 CFR 23.143(c) requires that values (expressed in pounds of force) may not exceed 75 pounds for temporary application with two hands on the wheel, 50 pounds for temporary application with one hand on the wheel, or 10 pounds for prolonged application. Force is applied at the wheel rim.

[15] Aircraft with trim-in-motion, or similar, systems include the DC-9/MD-80/717 series airplanes, Boeing 737, and Beech V35.

Board believes that the FAA should require Cessna to modify the Citation 525 to incorporate an aural trim-in-motion warning and the addition of contrasting color bands on the pitch trim wheel to provide the pilot with more timely recognition of a trim runaway condition before control forces become unmanageable.

Control Forces Associated With Cessna Citation 525 Trim Position

The Safety Board's investigation of the Penn Cove accident was not able to quantify the amount of nose-down force on the control column that resulted from the elevator trim runaway, nor could the pitch control forces described by Cessna's test pilot[16] be quantified. However, a comparison of the pilot statement and the pilot strength force limits outlined in 14 CFR 23.143(c) suggests that the forces experienced by the accident pilot exceeded the limits set in the regulations. Further, although the accident pilot reported that he did not notice the elevator trim position after he disconnected the autopilot, his account regarding the nose-down force and his comment that he thought the control forces were excessive immediately after autopilot disconnect suggest that the pitch control forces exceeded acceptable values before the pitch trim tabs had traveled to their full nose-down positions. As a result, the Safety Board is concerned that the control forces experienced in this accident exceeded the limits provided in the regulations and that further examination of the control forces associated with Citation 525 trim position is necessary.

Therefore, the Safety Board believes that the FAA should require Cessna to perform analysis and conduct a test to demonstrate that the maximum control forces in a Cessna Citation 525 meet the certification requirements of 14 CFR Part 23 during a pitch trim runaway condition. The analysis and test should comply with the pilot-recognition time requirements provided in AC 23-8. If, after accomplishing the analysis and test, Cessna is unable to demonstrate that the Citation 525 meets the certification requirements, require Cessna to take corrective action so that the airplane does meet certification requirements.

Identifying and Pulling the Pitch Trim Circuit Breaker to Arrest Elevator Trim Runaway in Cessna Citation 525s

As discussed previously, the only effective method for the accident pilot to arrest the pitch trim runaway after the K6 relay failure would have been to pull the pitch trim circuit breaker, which is one of an array of 69 identically sized, shaped, and colored circuit breakers located on the left-hand circuit breaker panel (the panel is located on the flight deck wall next to and just under the left armrest of the captain's [left] seat). Several of the circuit breakers are identified with color-coded collars, but the elevator/pitch trim circuit breaker is not. Postaccident inspection of the airplane confirmed that the pitch trim circuit breaker had not been pulled. The Safety Board notes that, given the pilot's report of the control forces involved, it is unlikely that he would have been able to quickly locate and pull the appropriate circuit breaker while maintaining control of the airplane. In addition, during airplane simulator trials, Cessna's test

[16] Cessna's test pilot indicated that the airplane's control forces were excessive after Cessna replicated the pitch trim runaway conditions in its aircraft simulator.

pilot, flying as a single pilot, was unable to counteract the control forces from similar elevator trim runaway conditions while attempting to pull the pitch trim circuit breaker.[17]

A pilot's rapid identification and disabling of the pitch trim circuit breaker is essential to effectively respond to the rapid increase and excessive magnitude of control forces during an elevator trim runaway in a Cessna Citation 525. However, a pilot's ability to do so is limited by the pitch trim circuit breaker's proximity to other circuit breakers of the same size and color. Therefore, the Safety Board believes that the FAA should require Cessna to replace the pitch trim circuit breaker in the Citation 525 with a collared circuit breaker to aid the pilot in quickly identifying it if necessary.

Therefore, the National Transportation Safety Board recommends that the Federal Aviation Administration:

> Require Cessna to modify the Citation 525 to incorporate an aural trim-in-motion warning and the addition of contrasting color bands on the pitch trim wheel to provide the pilot with more timely recognition of a trim runaway condition before control forces become unmanageable. (A-07-52)
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> Require Cessna to perform analysis and conduct a test to demonstrate that the maximum control forces in a Cessna Citation 525 meet the certification requirements of 14 *Code of Federal Regulations* Part 23 during a pitch trim runaway condition. The analysis and test should comply with the pilot-recognition time requirements provided in Advisory Circular 23-8, "Flight Test Guide for Certification of Part 23 Airplanes." If, after accomplishing the analysis and test, Cessna is unable to demonstrate that the Citation 525 meets the certification requirements, require Cessna to take corrective action so that the airplane does meet certification requirements. (A-07-53)
>
> Require Cessna to replace the pitch trim circuit breaker on the Citation 525 with a collared circuit breaker to aid the pilot in quickly identifying it if necessary. (A-07-54)

Please refer to Safety Recommendations A-07-52 through -54 in your reply. If you need additional information, you may call (202) 314-6177.

Chairman ROSENKER, Vice Chairman SUMWALT, and Members HERSMAN, HIGGINS, and CHEALANDER concurred with these recommendations.

[*Original Signed*]

By: Mark V. Rosenker
Chairman

[17] When a second pilot assisted with backpressure on the control column, the test pilot was able to locate and pull the pitch trim circuit breaker.