National Transportation Safety Board

Washington, D.C. 20594

Safety Recommendation

Date: April 16, 2001

In reply refer to: A-01-6 through -8

Honorable Jane F. Garvey
Administrator
Federal Aviation Administration
Washington, D.C. 20591

Since March 1998, the National Transportation Safety Board has learned of six airplanes on which flight control cable terminals have fractured. Additional terminals from some of these six airplanes and terminals from four other airplanes were also examined and found to be cracked. Nine of these 10 airplanes were Piper aircraft[1] that had at least one fractured or cracked MS21260-S4[2] terminal, illustrated in figure 1 (attached). The 10th airplane was a Cessna aircraft[3] on which an AN669[4] terminal, the precursor to the MS21260 terminal, was fractured. Metallurgical examinations conducted by the Safety Board determined that most of the terminals fractured or cracked through the shaft on the threaded end of the terminal, close to the wrench flats. A few of the terminals contained cracking in the

[1] Information on three of the airplanes is filed under NTSB accident No. MIA98-S-A149: (1) a 1979 Piper PA-28-161, N24TS, operated by an individual, Crystal Springs, Mississippi, March 19, 1998; (2) a 1977 Piper PA-28-161, N5680V, operated by an individual, Orlando, Florida, February 4, 2000; and (3) a 1979 Piper PA-44-180, N3060D, operated by Commair Aviation Academy, Miami, Florida, June 30, 2000. Information on two additional airplanes is filed under separate NTSB accident numbers: (4) a Piper PA-28-161, N8258A, operated by Florida Aviation Career Training, Inc., St. Augustine, Florida, September 28, 1998, 1981 (MIA98-S-A253); and (5) a 1980 Piper PA-28-161, N8085X, operated by an individual, Lawrenceville, Georgia, January 10, 1999 (MIA99-S-A085). Results of the Safety Board's materials laboratory examinations of the terminals from four additional airplanes are filed under the St. Augustine, Florida, accident (MIA98-S-A253): (6) a 1971 Piper PA-28-140, N648FL, Bad Axe, Michigan, October 5, 1998 (CHI99-L-A001); (7) a 1978 Piper PA-28-181, N39663, Montrose, Colorado, October 10, 1998, (DEN99-F-A009); (8) a 1979 Piper PA-44-180 airplane, Venice, Florida, located through a 1998 Federal Aviation Administration malfunction and defect report; and (9) a 1977 PA-28 airplane found in a salvage yard in Atlanta, Georgia.

[2] Military Standard MS21260, "Terminal, Wire Rope, Stud," specifies the sizes, thread directions, and materials that are allowed in the manufacture of the terminals in question. The terminals are constructed such that one end of the terminal can be swaged onto the end of a wire rope cable. The other end of the terminal contains threads that are inserted into a turnbuckle to the depth necessary to attain the proper cable tension. The middle portion of the terminal contains wrench flats and a safety wire hole.

[3] A 1967 Cessna 172H, N3788F, operated by a flying club, Quincy, Florida, July 1, 1999 (NTSB accident No. MIA99-S-A276).

[4] Air Force–Navy Aeronautical Standard AN669, "Terminal, Wire Rope, Stud," was the precursor to the MS21260 specification and was very similar to the MS21260 terminal in design and construction. AN669 was cancelled on November 25, 1963, and replaced by MS21260.

swaged end. The examinations identified chloride stress-corrosion cracking,[5] which had originated at general corrosion pits on the surface of the part, to be the fracture mode over most of the fracture surface of the terminals.

None of the terminal fractures resulted in a serious accident or loss of life. However, fractures and cracks in the Piper airplanes were in the stabilator control system, and three of the fractures occurred in flight. Although the control yoke became ineffective for pitch control, these three airplanes were landed without damage or injury to the passengers or crew. The Cessna fracture was in the aileron system and also occurred during flight, but the safety wire locking the terminal to the turnbuckle held the cable together and allowed the airplane to land safely.

All of the fractured and cracked MS21260 terminals (from the nine Piper airplanes) were manufactured by Bell-Memphis Inc., of Memphis, Tennessee, from SAE-AISI 303 Se[6] stainless steel. The Piper airplanes were manufactured between 1971 and 1981 and involved the Piper PA-28-161 model (four airplanes), other PA-28 models (three airplanes), and the Piper PA-44-180 model (two airplanes).

The Federal Aviation Administration's (FAA's) Service Difficulty Reporting System contained a report of the fractured AN669 terminal from the aileron system of the Cessna airplane, a 1967 Cessna 172H. Upon learning of this report 6 months after the broken terminal was found during maintenance, the Safety Board contacted the owner who was able to locate one-half of the terminal. Laboratory examination of the terminal half revealed stress-corrosion cracking of the same nature as that found previously on the Piper MS21260 terminals. The fractured Cessna terminal was manufactured by the Freeman Company. Although the AN669 specification provided a greater degree of flexibility in the material of construction, chemical analysis of the terminal material showed that its composition most closely matched that of an SAE-AISI 303 Se stainless steel.

Maintenance manuals for the Cessna 172 model include a security inspection for the terminals but no inspection for corrosion. Piper service manuals for the PA-28 and PA-44 models indicate that the cables and attachment hardware should be inspected during scheduled maintenance for items such as safety, damage, operation, security, routing, chafing, deterioration, wear, and correct installation. Although such an inspection may detect corrosion on the surface of the terminal, it does not specifically look for corrosion or instruct that the terminal must be replaced if corrosion pitting is found on the surface of the terminal.

All of the stress-corrosion cracks found to date have initiated from surface corrosion. Because the cracks are primarily subsurface, they can be difficult to detect. Corrosion pits on the surface of the

[5] Stress-corrosion is a synergistic effect of a sustained tensile stress and a corrosive atmosphere acting on a susceptible material, which, over time, may result in the fracture of a part at a stress significantly below the yield stress of the material.

[6] The Society of Automotive Engineers–American Iron and Steel Institute (SAE-AISI) specification for 303 Se, a free-machining grade of austenitic (200 and 300 series) stainless steel containing about 0.15 percent carbon, 2.0 percent manganese, 1.0 percent silicon, 17.0–19.0 percent chromium, 8.0–10.0 percent nickel, 0.2 percent phosphorous, 0.06 percent sulfur, and 0.15 percent selenium (minimum) by weight.

terminal may be the only condition that can be detected reliably during a visual inspection. The shaft area where the fractures have occurred is typically wrapped with safety wire, when safety wire is used instead of a clip-type lock. This area cannot be properly inspected without first removing the safety wire. Any inspection technique should therefore require removal of the safety wire before actual inspection of the terminal.

Stress-corrosion cracking occurs when a part made from a susceptible material is placed under a sustained tensile stress and subjected to a corrosive atmosphere. This cracking propagates as a function of time exposed in the environment (calendar-based), rather than time in flight. The age of the aircraft from which the recently fractured and cracked terminals were examined indicates that about 18–20 years is required for terminals exposed to the most damaging environment to reach their fracture point. The most damaging environment would be one in which the terminal is under high stress and the airplane operates in warm, humid, salty air.

The New Piper Aircraft, Inc., the current type certificate holder for Piper airplanes, has committed to revise each of its maintenance manuals to specifically require a magnified visual inspection of all cable fittings for corrosion during scheduled maintenance checks. Piper will begin by revising the manuals for the PA-28 and the PA-44, the models that were involved in the Piper fractures described in this letter, then by including the information in the next scheduled revision of the manuals for its remaining models. Inclusion of these inspections in the service manuals, however, will not make them mandatory, and years may elapse before Piper updates each of its maintenance manuals.

The MS21260 terminals and other such terminals are not life-limited, and the Safety Board is not aware of any civilian applications in which the terminals are required to be inspected to the degree necessary to detect stress-corrosion cracking; consequently, additional fractures may occur on airplanes where they have been installed. Although the terminal fractures investigated to date have not resulted in serious accidents or injuries, fracture of a terminal does cause a partial loss of control, which could lead to a serious accident, particularly if fracture occurs during a critical phase of flight or in combination with other factors such as a loss of engine power. Therefore, the Safety Board believes that the FAA should issue appropriate airworthiness directives, applicable to Piper PA-28, Piper PA-44, and Cessna 172 series airplanes older than 15 years,[7] to require recurrent visual inspections, on an appropriate, calendar-based interval, for evidence of corrosion pits or cracking on control cable terminals that were or may have been constructed from SAE-AISI 303 Se stainless steel. The inspections should be performed after removal of any safety wire or safety clips on the terminals. The FAA should also require that any terminals with signs of corrosion or cracking be removed from service immediately.

Stress-corrosion cracking on SAE-AISI 303 Se terminals is likely not unique to Piper, Cessna, or even general aviation airplanes. The U.S. Navy experienced a similar problem in 1987, when MS21260 terminals fractured on Lockheed P-3 airplanes as a result of chloride stress-corrosion cracking. The fractured terminals were made from SAE-AISI 303 Se stainless steel, manufactured by Bell-Memphis, and were one size smaller than the Piper terminals that the Safety Board examined. The

[7] Initiation of inspections at 15 years is recommended because this length of time is slightly less than the onset of cracking at 18–20 years.

U.S. Navy took corrective action by initiating a fleet-wide inspection of the terminals, with repeated inspections every 1,200 flight hours. Any terminal that showed external corrosion or cracking was removed and replaced. According to a representative of the U.S. Navy, no terminal fractures have been experienced since this corrective action was taken.

The fracture of MS21260 terminals on Piper airplanes, of an AN669 terminal on a Cessna airplane, and the difficulties encountered by the U.S. Navy with MS21260 terminals suggest that all terminals constructed from SAE-AISI 303 Se stainless steel, regardless of their size or the airplane on which they are installed, may be at risk. The fractures appear to reveal an inherent incompatibility between the austenitic stainless steel from which the terminals are manufactured and the environment to which they are exposed. Airplanes operating in a warm, humid, salty air environment are most likely to develop these stress corrosion cracks.

Discussions with various manufacturers of MS21260 terminals indicate that the majority of terminals manufactured today are made from SAE-AISI 303 Se stainless steel, although other materials are allowed by the specifications. These discussions also indicate that, although the specification was cancelled nearly 40 years ago, AN669 terminals are still being manufactured, from 303 Se stainless steel. A third type of terminal, NAS650, is very similar to both the MS21260 and AN669 terminals, including the option of constructing the terminal from 303 Se stainless steel and the possibility that it may be used in the aerospace industry. It is unknown whether additional terminal specifications of this type exist that allow for the use of 303 Se stainless steel.

Terminals like the MS21260 and AN669 are generic parts whose usage is widespread in a variety of aerospace applications. Piper has reportedly manufactured about 51,600 airplanes containing MS21260 terminals. Cessna representatives indicated that these types of terminals are used on most of their airplanes. According to representatives of Raytheon Aircraft Company, MS21260 terminals were widely used on Beech airplane models, on control cables and in other applications. A recent examination of a Bell Helicopter Model 47 helicopter revealed the presence of MS21260 terminals in its control system, and this type of terminal may be widely used in the construction of both helicopters and commercial aircraft. Therefore, the Safety Board believes that the FAA should determine which currently certificated aircraft models are authorized to have control cable terminals made from SAE-AISI 303 Se stainless steel, evaluate the need to require recurrent visual inspection, on an appropriate, calendar-based interval, of the terminals on these aircraft, and require such inspections if needed.

To date, the Safety Board is aware of only one fracture that has occurred on a general aviation aircraft manufactured by any company other than Piper. Piper reportedly applies a higher cable tension to the stabilator cables in its airplanes than does Beech to its control cables, which would provide a higher driving force for cracking and thus cause a faster crack growth rate on Piper airplanes. However, there does not appear to be a threshold stress below which chloride stress-corrosion cracking will not occur in austenitic (200 and 300 series) stainless steels. Not only does this mean that lowering the tension on affected cables would not correct this problem, but it also suggests that all manufacturers may encounter this problem at some point in the future. Consequently, the Safety Board believes that the FAA should immediately notify all manufacturers of both rotary and fixed-wing aircraft

of the cracking and corrosion problems currently being experienced with terminals made from SAE-AISI 303 Se stainless steel.

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

> Issue appropriate airworthiness directives, applicable to Piper PA-28, Piper PA-44, and Cessna 172 series airplanes older than 15 years, to require recurrent visual inspections, on an appropriate, calendar-based interval, for evidence of corrosion pits or cracking on control cable terminals that were or may have been constructed from SAE-AISI 303 Se stainless steel. The inspections should be performed after removal of any safety wire or safety clips on the terminals. Require that any terminals with signs of corrosion or cracking be removed from service immediately. (A-01-6)
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> Determine which currently certificated aircraft models are authorized to have control cable terminals made from SAE-AISI 303 Se stainless steel, evaluate the need to require recurrent visual inspection, on an appropriate, calendar-based interval, of the terminals on these aircraft, and require such inspections if needed. (A-01-7)
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> Immediately notify all manufacturers of both rotary and fixed-wing aircraft of the cracking and corrosion problems currently being experienced with terminals made from SAE-AISI 303 Se stainless steel. (A-01-8)

Acting Chairman CARMODY and Members HAMMERSCHMIDT, GOGLIA, and BLACK concurred in these recommendations.

Original Signed

By: Carol J. Carmody
Acting Chairman

Enclosure

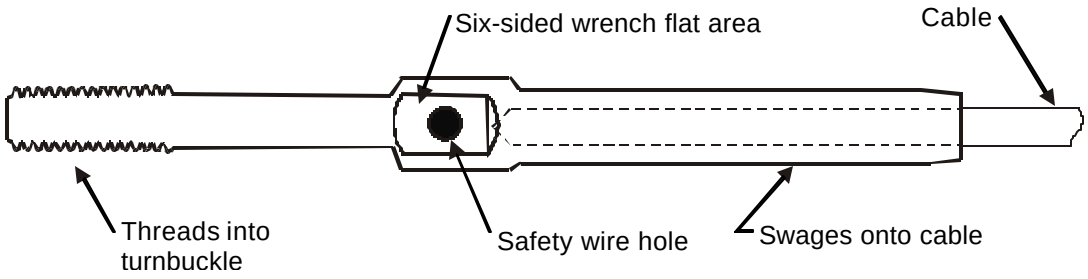

Figure 1. An MS21260-S4 terminal, drawn larger than actual size.