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National Transportation Safety Board

Washington, D.C. 20594

Safety Recommendation

Date: January 9, 1987

In reply refer to: A-86-132 through A-86-134

Honorable Donald D. Engen
Administrator
Federal Aviation Administration
Washington, D.C. 20591

On June 2, 1986, a Mitsubishi Model MU-2B-35, N8CC, crashed at Bartlett, Texas, killing the pilot. The National Transportation Safety Board's continuing investigation of the accident has disclosed circumstances which also appear relevant to other accidents involving Mitsubishi MU-2 airplanes. Shortly before the crash, just after ascending to and while attempting to maintain his assigned altitude of 9,000 feet, the pilot told the Houston International Airport departure controller that the airplane's autopilot was pitching the airplane nosedown and that he couldn't control the airplane. Subsequently, the airplane crashed into the ground at very high speed. The Model M-4C autopilot installed in this airplane was manufactured by the Avionics Division of the Bendix Corporation (Allied Bendix Aerospace). The autopilot incorporates a primary servo actuator containing two electromagnetic friction drive clutches and a capstan to move the elevator, and it has an elevator trim servo actuator with electrical and mechanical clutches to move the elevator trim tabs in the left and right elevators.

Other fatal accidents involving sudden loss of control of Mitsubishi MU-2 airplanes include uncontrolled collisions with the ground/water at Eola, Illinois, on March 5, 1986; at Jeffersonville, Georgia, on March 24, 1983; near Jacksonville, Florida, on November 19, 1981; at Saratoga, Wyoming, on November 5, 1981; at McLeod, Texas, on September 9, 1981; at Riverton, Wyoming, on September 6, 1981; at Ramsey, Minnesota, on December 6, 1980; at Bedford, New Hampshire, on August 28, 1978; and near Austin, Texas, on March 18, 1977. All of the airplanes involved in these accidents had Bendix M-4C or M-4D autopilots installed. The accidents at Bartlett, Texas, and Eola, Illinois, are still under investigation. All of the other accidents have occurred under mysterious circumstances and the probable cause of four of them has been classified as "undetermined."

As a result of these and other types of accidents involving the Mitsubishi MU-2, the Safety Board issued Safety Recommmendation A-83-56 on August 24, 1983. The Safety Board recommended that the Federal Aviation Administration (FAA) conduct a special certification review of Mitsubishi MU-2 airplanes relative to the engines, fuel system, autopilot, and flight control systems; flight in known icing conditions; engine inoperative characteristics; and handling characteristics during IMC landing approaches. Further, the Safety Board recommended that the FAA take appropriate action to correct any deficiencies identified in the review.

On April 18, 1979, the Safety Board issued Safety Recommendations A-79-21 through -24 in connection with several unexplained loss of control accidents involving Gates Learjet airplanes. The recommendations focused on the electromagnetic friction drive clutches in the airplane's autopilot servo drive units. These clutches are similar to those used in the Bendix M-4 series autopilots. An excerpt from these recommendations outlines the Safety Board's concern regarding these clutches:

> The pilot of a Learjet Model 24B, N14BC, reported longitudinal control problems on March 9, 1979, while enroute from Greensboro, North Carolina, to Nashville, Tennessee. While cruising at altitude, the aircraft abruptly pitched nosedown. The pilot regained control and deactivated the aircraft's stall warning system and automatic flight control system. After the aircraft was configured for landing, during an instrument approach to Nashville, it became longitudinally unstable. The pilot, who was unable to control the pitching oscillation, aborted the approach. As airspeed was increased, the aircraft became controllable. The pilot declared an emergency and returned to Greensboro where better weather existed. Similar problems were encountered while attempting to land at Greensboro. Three approaches were aborted before the aircraft was landed. The fourth approach was conducted without flaps, at a higher-than-normal airspeed, and with stabilizer trim for pitch control.
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> Postflight examination of the aircraft disclosed a resistance to motion of the longitudinal control system which was traced to the pitch axis servo drive unit. The unit was replaced and the aircraft was test flown without the control problems.
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> The National Transportation Safety Board took custody of the malfunctioning servo drive unit, and it was examined at the Gates Learjet plant in Wichita, Kansas. This unit consists of an electric motor which runs continuously in one direction when either the automatic pilot or the stall warning stickpusher system is energized. The output shaft of the motor drives a pair of electromagnetic friction drive clutches. These clutches rotate in opposite directions and their output shafts are connected to a common output, which in turn drives the elevator control surface. The clutches contain ferrous powder. Normally, this ferrous powder coagulates into a solid mass only when a magnetic field is introduced electrically by inputs from the autopilot or stall warning stickpusher system. The clutch, which is energized, will transmit torque to the elevator control system in the appropriate direction. The powder normally decoagulates and the clutch rotates freely when electrical power is removed.
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> Examination of the servo drive unit removed from N14BC revealed that the ferrous powder in the clutch which transmitted motion in the elevator trailing edge down direction was solid, although there was no electrical input. With the aircraft's autopilot or stall warning system activated, this condition would produce a nosedown pitching moment which could require as much as 80 pounds force on the control wheel to counter. With power removed from the servo motor, the jammed clutch would still affect the breakout force and force gradient of the longitudinal control system.

The other clutch of the servo was examined and it was free to rotate.

Gates Learjet personnel theorized that the powder coagulated and caused the clutch to jam because of moisture contamination. Reportedly, various degrees of moisture contamination and clutch engagement have been found on other servos that have been overhauled at Gates Learjet in the past.

The Safety Board was informed by the operator that the same aircraft experienced a lateral control problem on March 29, 1979. This time the aileron servo drive unit, identical to the pitch servo, was found to have a defective clutch.

The FAA's Operations Bulletin 79-3 "Malfunction of Pitch Servo Drive Unit Installed on Learjet Aircraft" issued in connection with this incident indicated, "It has been determined by Gates Learjet that the clutch malfunction was caused by magnetic powder packing because individual particles are worn smooth from constant agitation by the continuous running motor and an excessive amount of unlubricated powder in the clutches."

Gates Learjet subsequently provided an improved clutch assembly containing less powder and a small amount of dry lubricant for installation in the autopilot pitch axis servo. Nonetheless, a Learjet Model 25 equipped with the improved electromagnetic clutch was subsequently involved in a loss of pitch control incident attributable to packing or coagulation of the clutch powder. The FAA then issued Airworthiness Directive (AD) 80-22-10 applicable to Gates Learjet 23, 24, 25, 28, and 29 series airplanes requiring deactivation of the airplanes' autopilot pitch axis until, among other things, the existing pitch axis servo utilizing the electromagnetic clutch was replaced with a d.c. torque servo assembly.

AD 81-01-06, applicable to certain Bendix M-4 (A, B, C, and D) autopilot and YD-4 yaw damper primary servos with magnetic clutches, became effective January 12, 1981. The AD required inspection and modification of these servos in accordance with Bendix Service Bulletin M-4D-060 in order to prevent the possible failure of the primary servo due to seizure of the magnetic clutches.

Although the FAA did conduct a large-scale certification review in several areas of the MU-2 design as a result of Safety Recommendation A-83-56, an operational/engineering review and evaluation of the MU-2 autopilot system was specifically excluded. The FAA's decision not to conduct such a review of the autopilot may have relied heavily on "schematic logic" rather than potential autopilot faults stemming from mechanical design. However, during the past several years the only reported problems found in Service Difficulty Reports applicable to Bendix M-4 autopilots in MU-2 airplanes involved the autopilots' primary servo actuators. Almost all of the difficulties were caused by an inflight binding or seizure of the actuators as reflected in the following excerpts from these reports: "In flight, autopilot would not keep aircraft level; with autopilot disconnected there was still very little roll by using yoke; aircraft was landed with only 1 inch movement of wheel, spoilers would only extend 1/2 inch up, found servo frozen"; "Servo output shaft locked, motor seized, suspect magnetic clutch seized"; "Unable to disengage roll servo during descent, overpowered servo and eventually caused it to release"; "Ailerons [sic] seized inflight, found roll servo seized"; "Bearing on clutch seized making surface hard to control, control of yaw only by slipping capstan"; "Aileron [sic] control binding during flight after use of autopilot, pilot had to override aileron autopilot capstan slip clutch due to lockup"; and "Defective clutch."

The Bendix M-4 series autopilots are installed not only in MU-2 airplanes, but in a multitude of other airplanes as well, e.g., Gulfstream Commander 500/600 series, Beech King Air 90/100 series, Cessna 300/400 series, Embraer EMB-100 series, and Fairchild Merlin series airplanes. Most of these autopilot installations utilize primary servo actuators similar or identical to those used in the MU-2, i.e., primary servo model 3013H.

In view of the chronology of accidents involving sudden, unexplained loss of control of MU-2 airplanes equipped with Bendix M4 series autopilots; the generic similarity of the electromagnetic clutches used in the autopilot servos of the MU-2 with those formerly used in Gates Learjet airplanes; and the multitude of airplanes which use the Bendix M-4 series autopilots, the Safety Board believes that an operational/engineering review and evaluation of the MU-2 autopilot system is imperative. The review should specifically include a directed evaluation of the autopilot's altitude controller and the primary and electric trim servo assemblies (electromagnetic clutches, capstan and bridle cables, torque and torque setting mechanism, trim servo mechanical and electrical clutches, etc).

The Bendix Avionics Division maintenance manual for the M-4C autopilot system, reference I.B. 2004A, recommends periodic maintenance and testing of the autopilot system and accessories and replacement of critical items such as the electromagnetic clutches at specific intervals. For example, it is indicated that maintenance of the autopilot primary servo assembly should be performed as follows:

Maintenance Item	Flight Hours
Clean servo housing and gear teeth with solvent, relubricate gears, check motor, clutches and clutch brushes and replace if necessary.	800
Inspect gears and bearings and replace if necessary. Replace motor, both magnetic clutches and clutch brush assemblies.	1,600

Although N8CC had been operated for approximately 3,292 hours, the Safety Board could find no record of such maintenance having been performed on this airplane. Moreover, an examination of several of the primary servo electromagnetic clutches from the wreckage of N8CC disclosed evidence of moisture contamination and coagulation/solidfication of some of the clutches' ferrous powder. The forceful collision of N8CC with the ground may have affected the material state of the powder, and there may have been substantially more solidified powder present in the clutches prior to the crash.

Additionally, on February 29, 1980, according to Mitsubishi service records, an MU-2 airplane with a Bendix M-4 autopilot, N78HF, was involved in an incident in which the crew experienced extreme difficulty in maintaining lateral control of the airplane. The problem occurred when the output shaft of the primary roll servo became immovable. Consequently, even with the autopilot off, this required the crew to overcome the roll servo capstan clutch slip torque in order to move the spoilers. The slip torque should have been adjusted to 145 inch-pounds in this airplane but it was found set to 200 inch-pounds instead. As a result, the pilot was required to exert extraordinary force to control the airplane since the left hand grip of the copilot's control wheel was broken. Fortunately, there were two pilots aboard the airplane.

The immovable servo output shaft and the improper servo capstan torque are prima facie evidence that the autopilot on N78HF was not receiving the Bendix recommended periodic maintenance. Moreover, several sources have indicated to the Safety Board that generally periodic MU-2 autopilot maintenance is practically nonexistent and that maintenance is usually performed only when a gross autopilot malfunction is evidenced. However, the Safety Board believes that the aforementioned maintenance of the primary servos together with similar maintenance of the primary servo capstans (setting and adjustment of clutch slip torque) and electric trim servo assemblies is vital to continued safe operation of the Bendix M-4 series autopilots, particularly those installed in high-performance Mitsubishi MU-2 airplanes.

If the MU-2 autopilot or manual electric trim system malfunctions, the respective system may normally be disengaged using the appropriate disengage switch on the airplane's control wheel. However, the configuration, location, and color of these switches varies significantly among several MU-2 models and is confusing, even to experienced MU-2 pilots. For example, on June 30, 1986, a former Mitsubishi demonstration pilot flying an MU-2B-25, N780 CA, was involved in an incident at Mena, Arkansas, which illustrates the potential hazards of these operational-design variations. After takeoff, when the pilot engaged the autopilot (Bendix M-4 system) during climbout, the airplane rolled to the right because the autopilot's roll trim knob was adjusted to the full right position (the pilot had not performed an adequate preflight check of the autopilot). At the same time, however, a more serious problem with flight control occurred for unknown reasons. The airplane gradually pitched nose up and the pilot observed the pitch trim wheel to be running in the nose-up direction. Shortly thereafter, the pilot, primarily concerned with maintaining pitch control of the airplane, attempted to disengage the autopilot by pushing the red disengage button on the control wheel. However, this button was the airplane's electric trim disconnect switch. A similar red button had been used as the autopilot disconnect switch in the MU-2 model he previously had been accustomed to flying. Unaware that use of the electric trim switch would disengage the autopilot under any circumstances, the pilot eventually pulled the autopilot circuit breaker and used engine power and the manual trim wheel to bring the airplane under control. The outcome of this incident was fortuitous; i. e., the circumstances could easily have resulted in another fatal, unexplained MU-2 loss of control accident.

As a result, the Safety Board believes it essential for the manufacturer to issue an advisory notice to all MU-2 owner and operators regarding proper and safe operation of the autopilot system. The advisory should emphasize the proper operational procedure for preflight checks of the autopilot, warn against and explain why the pilot should not attempt to overpower the autopilot (because operation of the electric trim actuator, a part of the autopilot system, may eventually result in overwhelming stick forces), point out the design and functional differences of autopilot/electric trim disengage switches installed in the various MU-2 models, illustrate all the secondary means that may be used to disengage the autopilot (electric master switch, autopilot circuit breaker, etc.), emphasize the importance of assuring the readability of "autopilot disengage" and "electric trim disengage" markings on the control wheel (which often become illegible after an airplane has been in service for some time), and provide safety advisory guidelines (do's and don'ts) for proper use of the autopilot in all phases of flight.

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

Conduct a special certification review of the Bendix M-4 series autopilot systems and take the appropriate action to correct any deficiencies identified. The review should include an evaluation of the autopilot altitude controller, the autopilot primary servo assemblies including the electromagnetic clutches, the capstans and bridle cables, respective capstan torque criteria and torque adjusting mechanisms, and the autopilot electric trim servo assemblies including the mechanical and electric clutches. (Class II, Priority Action) (A-86-132)

Issue an Airworthiness Directive requiring periodic inspection, servicing, and testing of Bendix M-4 series autopilot systems installed in Mitsubishi MU-2 airplanes. Compliance with this requirement should include scheduled replacement of vital autopilot mechanical accessories such as servo motors, electromagnetic clutches, and clutch brush assemblies in accordance with the manufacturers' maintenance recommendations. (Class II, Priority Action) (A-86-133)

Require Mitsubishi Aircraft International, Incorporated, to issue an advisory notice to all Mitsubishi MU-2 owners and operators regarding proper and safe operation of the autopilot system. The advisory should emphasize the proper operational procedure for preflight checks of the autopilot, point out the design and functional differences of autopilot/electric trim disengage switches installed in the various MU-2 models, illustrate all the secondary means that may be used to disengage the autopilot, emphasize the importance of assuring the readability of "autopilot disengage" and "electric trim disengage" markings on the control wheel, and provide operational guidelines (do's and don'ts) for proper use of the autopilot in all phases of flight. (Class II, Priority Action) (A-86-134)

BURNETT, Chairman, GOLDMAN, Vice Chairman, and LAUBER and NALL, Members concurred in these recommendations.

By: Jim Burnett
Chairman