



# National Transportation Safety Board

Washington, D.C. 20594

## Safety Recommendation

---

**Date:** Oct 1, 2001

**In reply refer to:** A-01-41 through -48

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

---

On January 31, 2000, about 1621 Pacific standard time, Alaska Airlines, Inc., flight 261, a McDonnell Douglas MD-83 (MD-83), N963AS, crashed into the Pacific Ocean approximately 3 miles north of Anacapa Island, California. All 83 passengers and 5 crewmembers were killed, and the airplane was destroyed. Flight 261 was operating as a scheduled international passenger flight under the provisions of 14 *Code of Federal Regulations* Part 121 from Puerto Vallarta, Mexico, to Seattle, Washington, with an intermediate stop planned in San Francisco, California. Although the National Transportation Safety Board's investigation into the accident is ongoing,<sup>1</sup> evidence gathered to date raises concerns that warrant the Federal Aviation Administration's (FAA) attention regarding industry maintenance practices associated with the MD-80's horizontal stabilizer trim system and potential adverse effects caused by the use of inappropriate grease types or incompatible mixtures of grease types.

### **Background**

The horizontal stabilizer for the MD-83 (and also for all Douglas<sup>2</sup> DC-9 [DC-9], McDonnell Douglas MD-80/90 [MD-80/90], and Boeing 717<sup>3</sup> [717] series airplanes) is a critical flight control system located at the top of the vertical stabilizer. (See figure 1.) The horizontal stabilizer is hinged near its trailing edge so that the leading edge can traverse up and down to provide trim for the airplane in the pitch axis. The actuating mechanism for the horizontal stabilizer consists of an acme screw (attached to the horizontal stabilizer) that is rotated through a stationary acme nut attached to the vertical stabilizer. Up and down movement of the horizontal stabilizer is commanded automatically by the autopilot when it is engaged or manually by the flight crew by depressing a switch on the control wheel or by moving handles on the center

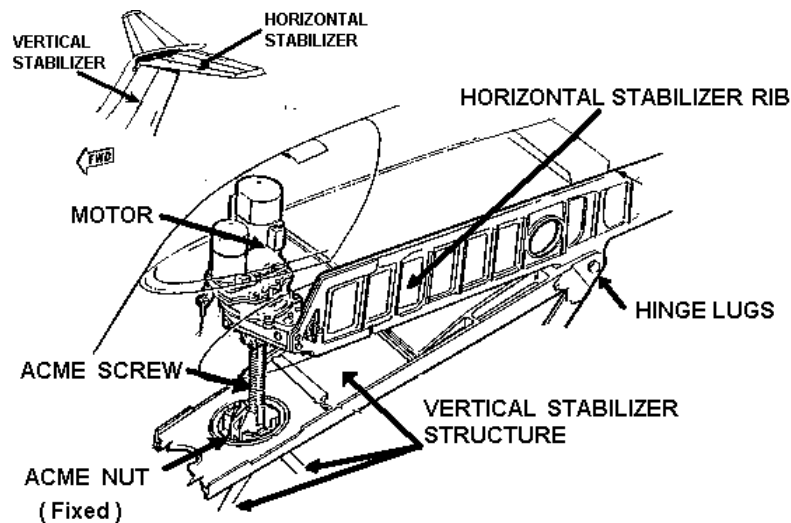
---

<sup>1</sup> The description for this accident, DCA00MA023, can be found on the Safety Board's Web site at <<http://www.ntsb.gov>>.

<sup>2</sup> The Douglas Aircraft Company became the McDonnell Douglas Corporation in 1967.

<sup>3</sup> After the Boeing Commercial Airplane Group acquired the McDonnell Douglas Corporation in 1997, the McDonnell Douglas MD-95 was renamed the Boeing 717.

pedestal. These actions activate an electric motor that rotates a titanium torque tube that is held fixed inside the acme screw by a retaining nut assembly at the lower end of the acme screw. (See figure 2.) The motor is deenergized whenever the trim commanded by the pilot or autopilot is achieved or when the horizontal stabilizer reaches its design (maximum travel) limits and activates a travel limit shutoff switch. A lower stop is installed on the acme screw just above the torque tube retaining nut assembly to stop acme screw rotation if the travel limit shutoff switch is misrigged or malfunctions. The MD-83 horizontal stabilizer's design limits its movement to about 12.2° leading edge down (airplane nose-up trim) and 2.1° leading edge up (airplane nose-down trim).

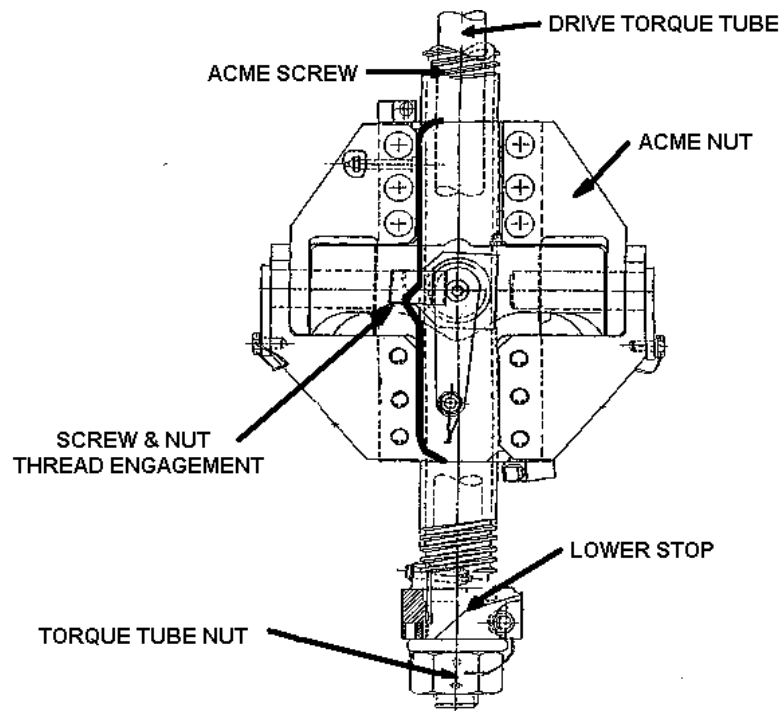


**Figure 1.** Horizontal stabilizer actuation system.

Performance data based on the accident airplane's flight data recorder indicate that the leading edge of the horizontal stabilizer rotated upward well beyond its design limit. Examination of the acme screw and nut from the accident airplane revealed that approximately 90 percent of the acme nut threads had worn away before the remainder of the acme nut threads stripped out. Those remnants were found wrapped around the acme screw.<sup>4</sup> The stripping of these threads would have allowed the acme screw to slip upward<sup>5</sup> through the acme nut until the lower stop impacted the bottom of the acme nut.

<sup>4</sup> The acme nut is manufactured from aluminum-bronze and is intended to wear, while the acme screw is manufactured from steel and is not intended to wear.

<sup>5</sup> The acme screw is held in tension (that is, it is pulled from above) both on the ground and during most phases of flight because of the location of the horizontal stabilizer's center of gravity and aerodynamic center of pressure relative to its pivot point.



**Figure 2.** Acme screw and nut assembly.

Examination of the lower stop revealed evidence of numerous strike marks, which is consistent with the lower stop repeatedly impacting the bottom of the acme nut. Additionally, the torque tube was fractured at its lower end, just above the torque tube nut.<sup>6</sup> Examination of the torque tube revealed evidence of low-cycle fatigue<sup>7</sup> cracking on a portion of this fracture, which is consistent with a failure caused by dynamic loads being imparted to the torque tube via repeated impacts of the lower stop on the acme nut. The fracture of the torque tube resulted in the separation of the lower stop and torque tube nut, which allowed the acme screw to slide up through the acme nut as the horizontal stabilizer was pulled beyond its upward design limit by aerodynamic loads. Aerodynamic studies indicate that the upward movement of the horizontal stabilizer's leading edge would have created an excessive aerodynamic tail load, resulting in the airplane pitching downward uncontrollably.

The Safety Board's review of DC-9, MD-80/90, and 717 series airplane certification documents revealed that the horizontal stabilizer trim system design assumed that the acme screw and nut threads were intact and engaged to act as a load path.<sup>8</sup> A review of the design and

<sup>6</sup> The torque tube nut and mating piece of the torque tube fracture were not recovered during the extensive salvage efforts.

<sup>7</sup> Low-cycle fatigue is metal fatigue that occurs over a relatively low number of cycles, with relatively high stress and plastic strain.

<sup>8</sup> The acme screw and nut design incorporates two independent thread spirals along their lengths. According to Boeing, this was intended to provide for redundant load paths at the threads in the event of a failure in one of the thread spirals.

certification data obtained in the Board's investigation to date indicates that no contingency for stripped acme nut threads was incorporated into the design for the horizontal stabilizer trim system on these airplanes.<sup>9</sup> Thus, the possibility of the acme screw disengaging from the acme nut was not formally considered during the certification process. The Board is continuing to research and evaluate the design and certification of the horizontal stabilizer trim system.

## **Horizontal Stabilizer Trim System Maintenance**

### **Lubrication**

During the public hearing on the Alaska Airlines flight 261 accident, which was held December 13 through 16, 2000, in Washington, D.C., engineers from Boeing Commercial Airplane Group (Boeing) testified that wear of the acme nut is normal and expected and is taken into account by its "robust" design. They further indicated that to maintain the horizontal stabilizer trim system's structural integrity, acme nut thread wear must be managed through (1) the regular application of lubrication and (2) an inspection program to monitor the wear. Boeing engineers also acknowledged that without such maintenance intervention, the type design could be compromised and the results could be catastrophic. An FAA certification engineer who testified at the public hearing agreed with these points.

According to the recommended horizontal stabilizer trim system lubrication procedure contained in Boeing's Airplane Maintenance Manual (AMM) for DC-9, MD-80/90, and 717 series airplanes, grease is to be periodically applied to an acme nut fitting under pressure until it is observed exiting the acme nut. The procedure also recommends the brush application of a light coat of the grease to the acme screw thread. The procedure then recommends operation of the system through its full range of travel to distribute the grease over the length of the acme screw.

The failure to properly lubricate the acme screw and nut could result in excessive acme nut thread wear rates. The Safety Board is aware of instances in which this occurred. For example, in 1984, three prematurely worn acme nuts were removed from three DC-9 airplanes and submitted to McDonnell Douglas for analysis. According to the McDonnell Douglas report, the cause of the premature wear was a lack of adequate lubrication. In 1990, another airline reported that a DC-9 horizontal stabilizer trim system acme nut had prematurely worn. McDonnell Douglas again concluded that the cause of the excessive wear rate was a lack of adequate lubrication.<sup>10</sup>

---

<sup>9</sup> The Safety Board requested all available documentation addressing the certification of these airplane designs. Documentation provided by Boeing included the April 15, 1965, DC-9 Flight Controls System Fault Analysis Report (revised July 14, 1997); the 1964 DC-9 Control System Design Criteria Report; and the April 1998 MD-95-30 Control Systems Loads and Criteria Report. Additionally, internal design memorandums that addressed the horizontal stabilizer trim system were reviewed. None of the documentation mentioned or addressed a failure mode involving excessive wear or stripping of the acme nut threads.

<sup>10</sup> In All Operators Letter 9-2120A, dated September 5, 1991, McDonnell Douglas indicated that average in-service wear rates for the DC-9 and MD-80 were 0.0011 and 0.0013 inches per 1,000 flight hours, respectively.

During this investigation, Safety Board investigators observed lubrications of acme screw and nut assemblies performed by maintenance personnel from two MD-80 operators and discussed the lubrication procedure with those and other maintenance personnel from those operators. Investigators noted that there were differences in the methods used by those personnel to accomplish certain steps in the lubrication procedure, including the manner in which grease was applied to the acme nut fitting and the acme screw and the number of times the trim system was cycled to distribute the grease immediately after grease application. Demonstrations<sup>11</sup> designed to compare the effectiveness of various methods of lubricating the acme nut and screw assembly found that a thorough application of grease onto the entire length of the acme screw, followed by the cycling of the trim several times, maximized the lubrication of the acme nut threads. Several of the methods observed by or reported to investigators did not involve application of grease to the entire length of the acme screw and cycling the trim several times. As a result, the Board is concerned that the current lubrication procedure may not be adequate to ensure consistent and thorough lubrications of the acme screw and nut assembly by all operators. Therefore, the Safety Board believes that the FAA should require Boeing to revise the lubrication procedure for the horizontal stabilizer trim system of DC-9, MD-80/90, and 717 series airplanes to minimize the probability of inadequate lubrication.

### **End Play Check**

The required inspection procedure to monitor the acme nut thread wear is described in Airworthiness Directive (AD) 2000 15-15, which was issued August 23, 2000, as a result of the accident. This procedure, commonly known as an end play check, involves pulling down on the horizontal stabilizer by applying a specified amount of torque to a restraining fixture (tool) to change the load on the acme screw from tension to compression. The change in load causes movement between the acme nut and the acme screw that can be measured with a dial indicator. The amount of movement, or end play, is indicative of the amount of wear in the threads of the acme nut (and the acme screw if it is also worn). The restraining fixture has a threaded midsection with a threaded clevis screwed into each end and must be adequately lubricated to provide accurate measurements.<sup>12</sup> The dial indicator is an instrument used to measure small amounts of linear movement between two points. The movement is picked up by a plunger at the back of the indicator and read in thousandths of an inch. The dial indicator is mounted to the lower rotational stop with the plunger set against the lower surface of the acme nut, which measures relative movement between the acme screw and the acme nut. The restraining fixture load is applied and removed several times until consistent measurements are achieved.

The failure to properly perform the end play check procedure or to monitor the wear of the acme nut may result in continued operation of an airplane with potentially excessive acme nut thread wear. The investigation has indicated that the end play check procedure techniques are susceptible to measurement error. During this investigation, Safety Board investigators observed

---

<sup>11</sup> The demonstrations involved the use of acme nuts that were manufactured from a translucent plastic, which afforded a view of the acme nut threads during lubrication and operation of an acme screw that was rotated through the nut under a static load.

<sup>12</sup> A specified amount of torque is applied to the midsection of the restraining fixture through the use of a torque wrench to cause the change in load on the acme screw.

end play checks performed by maintenance personnel from several MD-80 operators. It was noted that the accuracy of the results could be affected by deviations in one or more of the following areas: (1) proper calibration and interpretation of the dial indicators; (2) proper installation of the dial indicator; (3) correct application and direction of the specified torque to the restraining fixture; (4) use of a correctly fabricated, lubricated, and maintained restraining fixture; (5) rotation of the acme screw within its gearbox during the procedure and its effect on the movement of the dial indicator plunger; and (6) the individual mechanic's knowledge of the procedures. A review of end play measurements that have been reported pursuant to AD 2000 15-15<sup>13</sup> indicates that many operators are continuing to obtain highly variable end play readings. Additionally, the Board's preliminary analysis of these data indicates significant variability in end play measurements that reflects statistical unreliability in the end play measurement procedure.

During some of the end play check observations, Safety Board investigators evaluated whether different methods of accomplishing the end play check procedure could either increase or decrease the likelihood of measurement error or the reliability of the measurement from one end play check to the next. Investigators found that when the dial indicator was mounted above the acme nut instead of below it (as is called for in the current end play check procedure), the likelihood of measurement error was decreased. Specifically, the dial indicator was easier to install in this position, its face could be seen more easily (without the need for an inspection mirror, as was the case when it was installed below the acme nut), and the end play reading could be more easily discerned from the movement of the indicator needle.<sup>14</sup> Investigators also found that when the dial indicator was mounted such that the plunger contacted the canted surface of the acme nut stop lug at a skewed angle to the plunger axis, the end play reading was lower than it was when it contacted a level surface on the acme nut at a right angle to the plunger axis. When the dial indicator was mounted such that the plunger contacted a level surface on the acme nut at a right angle to the plunger axis, more accurate readings were obtained. The current end play check procedure does not stipulate specifically how and where the dial indicator plunger should contact the acme nut.

Based on these results, the Safety Board is concerned that the current end play check procedure may not be adequate to ensure consistent, accurate, and reliable measurements of acme screw and nut wear. Therefore, the Safety Board believes that the FAA should require the Boeing Commercial Airplane Group to revise the end play check procedure for the horizontal stabilizer trim system of Douglas DC-9, McDonnell Douglas MD-80/90, and Boeing 717 series airplanes to minimize the probability of measurement error and conduct a study to empirically validate the revised procedure against an appropriate physical standard of actual acme screw and

---

<sup>13</sup> AD 2000 15-15 requires all U.S. operators of DC-9, MD-80/90, and 717 series airplanes to perform the end play check every 2,000 flight hours and report the end play measurements to the manufacturer after every check. Before the Alaska Airlines flight 261 accident, operators performed the check at various intervals that exceeded 2,000 hours, depending upon the approval of each airline's maintenance program by the airline's FAA principal maintenance inspector (PMI).

<sup>14</sup> When the dial indicator was mounted below the acme nut, as called for in the current procedure, the dial indicator plunger moved upward as the acme nut moved, causing the needle to move counterclockwise, or opposite the intended direction. This movement required maintenance personnel to read the indicator backwards and interpret the total needle movement in order to obtain the end play.

acme nut wear. This study should also establish that the procedure produces a measurement that is reliable when conducted on-wing.

The lubrication and end play inspection of the acme screw and nut assembly are only two of hundreds of regularly scheduled maintenance items that are specified in the Boeing AMM. Although Federal Aviation Regulations (FAR) require operators to have a “training program” to ensure that maintenance personnel are competent to perform all maintenance tasks,<sup>15</sup> most airlines comply with this requirement by conducting general aircraft familiarization courses and on-the-job training. The Safety Board notes that operators rarely provide detailed specialized training for specific maintenance tasks.<sup>16</sup> Additionally, the Board is not aware of any operator that requires its mechanics to be formally trained to perform the lubrication and end play inspection of the acme screw and nut assembly. The Board also notes that the FARs do not require any such training.

Because of the known potential for catastrophic results from excessive acme nut thread wear, the Safety Board is concerned that the FAA does not require that maintenance personnel who lubricate and inspect the horizontal stabilizer trim system be formally trained and qualified. Additionally, the Board is concerned that the FAA does not require maintenance personnel to be familiarized with the selection, inspection, and proper use of the tooling required to perform the end play check. Therefore, the Board believes that the FAA should require maintenance personnel who lubricate the horizontal stabilizer trim system of DC-9, MD-80/90, and 717 series airplanes to undergo specialized training for this task. The Board also believes that the FAA should require maintenance personnel who inspect the horizontal stabilizer trim system of DC-9, MD-80/90, and 717 series airplanes to undergo specialized training for this task. This training should include familiarization with the selection, inspection, and proper use of the tooling to perform the end play check.

### **Potential Adverse Effects Caused by the Use of Inappropriate Grease Types or Incompatible Mixtures of Grease Types**

Boeing’s AMM for DC-9, MD-80/90, and 717 series airplanes specifies the use of Mil-G-81322<sup>17</sup> grease to lubricate the acme screw and nut assembly. Initially, Alaska Airlines used Mobilgrease 28, which meets the specifications of Mil-G-81322.<sup>18</sup> Mobilgrease 28 has a

---

<sup>15</sup> FAR Part 121.375, titled “Maintenance and preventive maintenance training program,” states: “Each certificate holder or person performing maintenance or preventive maintenance functions for it shall have a training program to ensure that each person (including inspection personnel) who determines the adequacy of work done is fully informed about procedures and techniques and new equipment in use and is competent to perform his duties.”

<sup>16</sup> Examples of these specialized qualifications include aircraft taxiing and non-destructive inspection of turbine engine components.

<sup>17</sup> The “Mil” specification is a U.S. military material specification that defines the requirements for a material and is approved after a process of testing and review. Requirements that are defined for grease Mil specification categories include, in part, viscosity, temperature range, and corrosion protection. A part’s function and exposure to such factors as loads, friction, extreme temperatures, and water and other contaminants determine which grease Mil specification category is appropriate.

<sup>18</sup> Several brand names may meet a specific Mil specification, and these greases are listed on the Qualified Products List for each Mil specification. For example, greases that meet the specifications for Mil-G-81322 include Mobilgrease 28, Aeroshell Grease 22, and Royco Grease 22.

clay-based thickening agent. In December 1997, Alaska Airlines modified its maintenance instructions<sup>19</sup> to specify the use of Aeroshell Grease 33 to lubricate the acme screw and nut assembly.<sup>20</sup> Aeroshell Grease 33 is a relatively new type of grease that was developed for Boeing and subsequently qualified under Mil-PRF-23827 (formerly Mil-G-23827).<sup>21</sup> Aeroshell Grease 33 has a lithium soap-based thickening agent.

The Safety Board found that Boeing had previously expressed concern about mixing greases thickened with clay with those thickened with lithium soaps. This concern was documented in Boeing Service Letter (SL) 737-SL-20-27, dated August 12, 1993, which stated that “some incompatibility may exist between MIL-G-23827 greases that are thickened with clay and those that are thickened with lithium soap. Therefore, intermixing of brand name greases that employ different thickening systems should be avoided.” The SL also stated that “MIL-G-23827 grease is incompatible with MIL-G-81322 grease.” In addition, in an SL dated June 30, 1997, titled, “Summary of Most Commonly Used Greases on Boeing Airplanes,” Boeing again stated that Mil-G-23827 grease was incompatible with Mil-G-81322 grease and that “the two greases should not be mixed.”

Before modifying its maintenance program in December 1997, Alaska Airlines asked the airplane manufacturer (McDonnell Douglas at that time) about using Aeroshell Grease 33 instead of Mil-G-81322 (Mobilgrease 28). On September 26, 1997, McDonnell Douglas responded as follows:

Douglas has no technical objection to the use of [Aeroshell 33] grease in place of MIL-G-81322 grease on Alaska Airlines MD-80 aircraft.... This no technical objection is provided prior to the completion of a Douglas study intended to determine the acceptability of Aeroshell 33 grease for use in Douglas-built aircraft.<sup>[22]</sup> As such, Douglas cannot yet verify the performance of this grease. It will be the responsibility of Alaska Airlines to monitor the areas where Aeroshell 33 grease is used for any adverse reactions. Further, it will be the responsibility of Alaska Airlines to obtain FAA approval required by their principal maintenance inspector for the use of Aeroshell 33 grease in their MD-80 aircraft.

Although Alaska Airlines notified the FAA in December 1997 of the change in the grease type specified in its maintenance instructions, as required, it did not provide any substantiating justification at that time nor was such action required.<sup>23</sup> The FAA did not request documentation

---

<sup>19</sup>According to Alaska Airlines, this modification was made as part of an effort to standardize and reduce the number of greases used by the airline in its mixed fleet of 737s and MD-80s.

<sup>20</sup> Alaska Airlines used Aeroshell Grease 33 to lubricate flight controls, including the acme screw and nut assembly, doors, and landing gear (except wheel bearings) on MD-80 series airplanes.

<sup>21</sup> Mil-PRF-23827 superseded Mil-G-23827 in 1998. No significant changes to the specification were made other than to change the standard’s designation number.

<sup>22</sup> According to Boeing, Douglas never completed such a study.

<sup>23</sup> The notification of lubrication change was included as part of a monthly maintenance task card audit report that Alaska Airlines provided to the FAA. The monthly audit report included all task card changes, including revision dates, made by the airline since its last report. The FAA PMI for Alaska Airlines at the time of the lubrication



supporting the change until March 2000, after concerns were raised in connection with the Alaska Airlines flight 261 investigation. Alaska Airlines subsequently submitted the requested documentation.<sup>24</sup> In an April 5, 2000, response letter, the FAA stated to Alaska Airlines that the substantiating documents it had submitted did not support the change, and it disapproved the use of Aeroshell Grease 33 as a substitute for Mobilgrease 28. Alaska Airlines subsequently modified its maintenance procedures to specify the use of Mobilgrease 28 on the horizontal stabilizer trim systems of its MD-80s.

Examination of the wreckage from Alaska Airlines flight 261 revealed numerous globules of red grease, the composition of which was consistent with Mobilgrease 28, on the exterior of the acme nut and the presence of degraded grease just below the area of the acme screw's normal travel. The Safety Board commissioned the U.S. Naval Air System Command's Aerospace Materials Laboratory at Patuxent River, Maryland, to evaluate a sample of this degraded grease. The results from the laboratory evaluation revealed that the sample contained remnants of both Aeroshell Grease 33 and Mobilgrease 28.

Subsequently, in April 2000, the Safety Board commissioned the U.S. Navy's Aerospace Materials Laboratory to evaluate the compatibility of Mobilgrease 28 and Aeroshell Grease 33 using the American Society for Testing and Materials (ASTM) Test Method D-6185. ASTM D-6185 is used to evaluate the compatibility of combinations of two different types of lubricating greases. According to ASTM D-6185, compatibility is "the characteristic of lubricating greases to be mixed together without significant degradation of properties or performance," and incompatibility is most often manifested by a degradation in physical properties.<sup>25</sup> Results of the testing indicated that Mobilgrease 28 and Aeroshell Grease 33 are incompatible at the 90/10 and 10/90 ratios but not at the 50/50 ratio.<sup>26</sup>

---

change stated during postaccident interviews that such changes could be made without prior FAA approval under provisions of the airline's FAA-approved maintenance program. According to the PMI, changes to "accepted [maintenance] manuals" used as part of an overall FAA-approved maintenance program can be made and then submitted to the FAA as part of a routine change notification process. The PMI stated, "in accepted manuals, they go ahead and make the change, publish it, and send you a copy and you read it. And if you have any objection to it, [you] notify them in writing that you have objections. If you don't tell them, then it's accepted." Referring to the Alaska Airlines lubrication change and the task card change notification in 1997, the PMI stated, "I don't know that anybody caught that or noticed it or bought off on it or looked into it at all."

<sup>24</sup> The Safety Board requested all of the documents that were submitted by Alaska Airlines to the FAA. The documents included a trade magazine article on Aeroshell Grease 33, excerpts of Boeing 737 and McDonnell Douglas MD-80 maintenance manuals, Boeing SLs, internal correspondence and messages between Alaska Airlines and Boeing, and existing specifications on Mil-G-81322 and Mil-G-23827 greases. None of the documents provided any information or performance data specifically applicable to the use of Aeroshell Grease 33 on McDonnell Douglas airplanes or these airplanes' horizontal stabilizer trim systems.

<sup>25</sup> According to the *Lubricating Grease Guide*, published by the National Lubricating Grease Institute, "when greases made from different thickeners are mixed, the mixture may be poorer in service performance or physical properties than either of the component products." The guide also states that incompatibility "may show up in any of several areas, such as (1) lower heat resistance; (2) change in consistency, usually softening; or (3) decrease in shear stability."

<sup>26</sup> ASTM D-6185 specifies that the two greases being evaluated be blended into specific ratios. The 50/50 ratio simulates the condition when one grease is added to a bearing that contains another grease. The 90/10 and 10/90 ratios simulate attempts to flush out one grease with another. A failure in any of the tested properties indicates an

The U.S. Navy's Aerospace Materials Laboratory also conducted corrosion tests of copper and aluminum bronze in contact with both pure quantities and mixed quantities of Mobilgrease 28 and Aeroshell Grease 33. Aeroshell Grease 33 failed the partial submersion test on copper<sup>27</sup> by producing a visible stain to the copper surface. After modifying the test methods to incorporate the use of aluminum bronze as the test specimen, Aeroshell Grease 33 produced visually similar discolorations. Additionally, certain mixture ratios of Aeroshell Grease 33 and Mobilgrease 28 caused discolorations of the aluminum bronze surfaces. The Safety Board is currently conducting tests to determine the nature of these stains.

Although the Safety Board has not yet determined whether, or the extent to which, the application of Aeroshell Grease 33 or a combination of Mobilgrease 28 and Aeroshell Grease 33 might have adversely affected the wear characteristics of the horizontal stabilizer acme screw and nut assembly on Alaska Airlines flight 261, the Board is concerned that Alaska Airlines began using Aeroshell Grease 33, and the FAA did not object to this use, without sufficient research, testing, or tracking of in-service data to demonstrate its acceptability. Because potential adverse effects can be caused by the use of an inappropriate grease type or an incompatible mixture of grease types, the Safety Board believes that the FAA should, before the implementation of any proposed changes in allowable lubrication applications for critical aircraft systems, require operators to supply to the FAA technical data (including performance information and test results) demonstrating that the proposed changes will not present any potential hazards and obtain approval of the proposed changes from the principal maintenance inspector (PMI) and concurrence from the applicable FAA aircraft certification office. Further, the Safety Board believes that the FAA should issue guidance to PMIs to notify all operators about the potential hazards of using inappropriate grease types and mixing incompatible grease types.

During the public hearing on the Alaska Airlines flight 261 accident, testimony from FAA inspectors and managers indicated that the control, approval process, and monitoring of airline lubrication practices may not be adequate to ensure that inappropriate grease types or incompatible grease mixtures are not being used.<sup>28</sup> Based on this testimony, the Safety Board is concerned that some airlines may have implemented changes to their lubrication practices that could be detrimental to the safe operation of critical aircraft systems and that these changes did not receive adequate review and approval from the FAA. Therefore, the Safety Board believes

---

incompatibility of the two greases. According to the preliminary report of the test results, incompatibility existing at the 90/10 and 10/90 ratios, but not at the 50/50 ratio, is unusual but not unprecedented.

<sup>27</sup> Two test methods were used. ASTM Method 4048 specifies that a copper specimen be completely submerged in a quantity of grease for 24 hours at 100° Celsius (C). Federal Test Method Standard 791, Method 5309.5, specifies that a copper specimen be partially submerged in a quantity of grease for 24 hours at 100° C.

<sup>28</sup> During the public hearing, an FAA inspector who was acting as Alaska Airline's PMI after the accident testified that "there would have probably been nothing to drive" the FAA to require sufficient justification for the grease change before the accident "unless some indicators starting [*sic*] showing up." The inspector also stated "there is always the chance that things are going to slip through" whenever the FAA reviews changes to maintenance procedures that have been made by an airline. Additionally, the Director of the FAA's Flight Standards Service testified that he did not know "how a field inspector would react to seeing a [grease change] in the paperwork that flows across [his desk]." And that "it's impossible...to do a thorough review every month" of audit reports that PMIs receive when maintenance task cards are changed. The director also stated that there are no policies within the Flight Standards Service that ensures that every task card change notification is reviewed.

that the FAA should survey all operators to identify any lubrication practices that deviate from those specified in the manufacturer's AMM, determine whether any of those deviations involve the current use of inappropriate grease types or incompatible grease mixtures on critical aircraft systems, and, if so, eliminate the use of any such inappropriate grease types or incompatible mixtures.

During the course of this investigation, Safety Board investigators became aware that information about grease, including grease specifications, characteristics, performance, and applications, is available from numerous sources. These sources include grease manufacturers, grease qualifying authorities, equipment manufacturers, tribological<sup>29</sup> test laboratories and researchers, and aircraft maintenance organizations. Investigators found that each of these sources had a significant amount of relevant information and knowledge; however, in many cases, one or more of these sources were unaware of information that was well known by another source. For example, one or more of these sources were unaware of the details pertaining to the potential for incompatibility of grease types within the same Mil specification; information about incompatibility of grease types from different Mil specifications; proper methods for identification and selection of grease for specific applications; the Mil specification qualification process; grease manufacturers' recommended uses for specific greases; machinery manufacturers' recommended greases; proper storage methods for various grease types; and the proper methods for application of grease.

The Safety Board is concerned that a significant amount of useful technical information and practical experience is not being shared among relevant organizations involved in the lubrication, aviation, and equipment industries. Improved dissemination of such information would enhance the awareness of potential hazards associated with the lubrication of critical aircraft components. Therefore, the Safety Board believes that the FAA should, within the next 120 days, convene an industrywide forum to disseminate information about and discuss issues pertaining to the lubrication of aircraft components, including the qualification, selection, application methods, performance, inspection, testing, and incompatibility of grease types used on aircraft components.

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

Require the Boeing Commercial Airplane Group to revise the lubrication procedure for the horizontal stabilizer trim system of Douglas DC-9, McDonnell Douglas MD-80/90, and Boeing 717 series airplanes to minimize the probability of inadequate lubrication. (A-01-41)

Require the Boeing Commercial Airplane Group to revise the end play check procedure for the horizontal stabilizer trim system of Douglas DC-9, McDonnell Douglas MD-80/90, and Boeing 717 series airplanes to minimize the probability of measurement error and conduct a study to empirically validate the revised

---

<sup>29</sup> Tribology is the science of the mechanisms of friction, lubrication, and wear of interacting surfaces that are in relative motion.

procedure against an appropriate physical standard of actual acme screw and acme nut wear. This study should also establish that the procedure produces a measurement that is reliable when conducted on-wing. (A-01-42)

Require maintenance personnel who lubricate the horizontal stabilizer trim system of Douglas DC-9, McDonnell Douglas MD-80/90, and Boeing 717 series airplanes to undergo specialized training for this task. (A-01-43)

Require maintenance personnel who inspect the horizontal stabilizer trim system of Douglas DC-9, McDonnell Douglas MD-80/90, and Boeing 717 series airplanes to undergo specialized training for this task. This training should include familiarization with the selection, inspection, and proper use of the tooling to perform the end play check. (A-01-44)

Before the implementation of any proposed changes in allowable lubrication applications for critical aircraft systems, require operators to supply to the FAA technical data (including performance information and test results) demonstrating that the proposed changes will not present any potential hazards and obtain approval of the proposed changes from the principal maintenance inspector and concurrence from the FAA applicable aircraft certification office. (A-01-45)

Issue guidance to principal maintenance inspectors to notify all operators about the potential hazards of using inappropriate grease types and mixing incompatible grease types. (A-01-46)

Survey all operators to identify any lubrication practices that deviate from those specified in the manufacturer's airplane maintenance manual, determine whether any of those deviations involve the current use of inappropriate grease types or incompatible grease mixtures on critical aircraft systems and, if so, eliminate the use of any such inappropriate grease types or incompatible mixtures. (A-01-47)

Within the next 120 days, convene an industrywide forum to disseminate information about and discuss issues pertaining to the lubrication of aircraft components, including the qualification, selection, application methods, performance, inspection, testing, and incompatibility of grease types used on aircraft components. (A-01-48)

Vice Chairman CARMODY<sup>30</sup> and Members HAMMERSCHMIDT, GOGLIA, and BLACK concurred in these recommendations.

By: Marion C. Blakey  
Chairman

---

<sup>30</sup> At the time she cast her vote, Vice Chairman Carmody was serving as the Board's Acting Chairman. Marion C. Blakey did not participate in deliberations on this matter.