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Failure of Stabilizer-trim System Blamed For Crew's Loss of Control of MD-83

Insufficient lubrication led to excessive wear and to failure of the jackscrew assembly in the McDonnell Douglas MD-83's horizontal-stabilizer-trim system. The failure caused the horizontal stabilizer to jam in a position beyond normal limits and the aircraft to enter a nose-down pitch attitude from which recovery was not possible.

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FSF Editorial Staff

At 1621 local time Jan. 31, 2000, a McDonnell Douglas MD-83, being operated as Alaska Airlines Flight 261, struck the Pacific Ocean about 2.7 nautical miles (5.0 kilometers) north of Anacapa Island, California, U.S. The two pilots, three cabin crewmembers and 83 passengers were killed. The airplane was destroyed.

The U.S. National Transportation Safety Board (NTSB) said, in its final report, that the probable cause of the accident was "a loss of airplane-pitch control resulting from the in-flight failure of the horizontal-stabilizer-trim-system jackscrew assembly's acme-nut threads. The thread failure was caused by excessive wear resulting from Alaska Airlines' insufficient lubrication of the jackscrew assembly.

"Contributing to the accident were Alaska Airlines' extended lubrication interval and the [U.S.] Federal Aviation Administration's (FAA) approval of that extension, which increased the likelihood that a missed [lubrication] or inadequate lubrication would result in excessive wear of the acme-nut threads, and Alaska Airlines' extended end-play-check interval and the FAA's approval of that extension, which allowed the excessive wear of the acme-nut threads to progress to failure without the opportunity for detection.

"Also contributing to the accident was the absence on the [MD-80] of a fail-safe mechanism to prevent the catastrophic effects of total acme-nut thread loss."

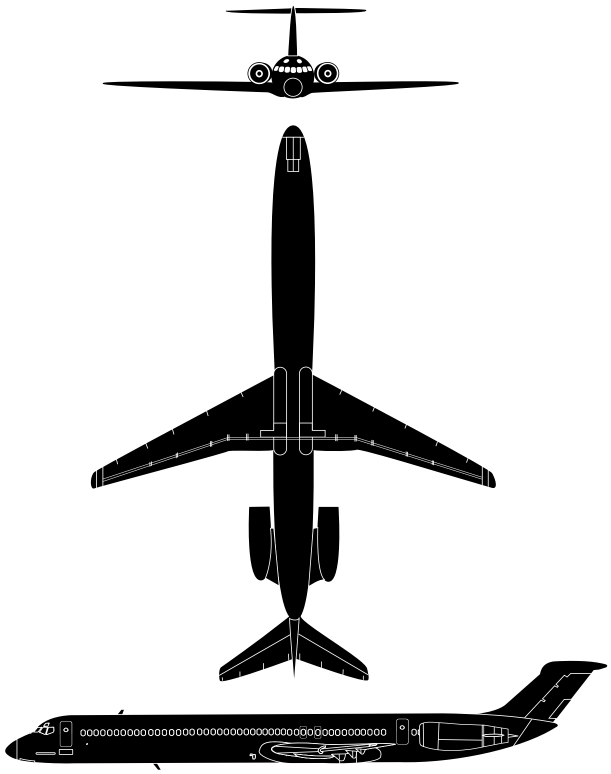
The airplane was being operated on a scheduled flight from Puerto Vallarta, Mexico, to Seattle, Washington, U.S., with an en route stop at San Francisco, California, U.S. Visual meteorological conditions prevailed along the route of flight.

The captain, 53, had about 17,750 flight hours, including 4,150 hours as pilot-in-command of MD-80 series airplanes.

The first officer, 57, had about 8,140 flight hours, including about 8,060 flight hours as a first officer in MD-80 series airplanes.

The accident airplane was manufactured in 1992 and began service with Alaska Airlines in 1992. The airplane had accumulated 26,584 operating hours and 14,315 flight cycles (takeoffs and landings).

The report said that flight data recorder (FDR) data indicated that the longitudinal-trim-control system functioned normally



McDonnell Douglas MD-83

The MD-80 series jet transports are derivatives of the Douglas DC-9, which first flew in 1965. Douglas Aircraft Co. and McDonnell Co. merged in 1967 to form McDonnell Douglas Corp. The MD-80, originally called the Super 80, has longer wings, a longer fuselage and more fuel capacity than the DC-9, and an integrated digital flight control system.

The MD-80 prototype flew in 1979, and the airplane entered production in 1980 as the MD-81. Production of the MD-82 began in 1981. The MD-83, which first flew in 1984, is the same size as the MD-81 and MD-82, and has the same passenger capacity (172 passengers, maximum). The MD-83 has more fuel capacity, more fuel-efficient engines and, thus, greater range than its predecessors. The increased fuel capacity was derived by the installation of two extra tanks in the cargo compartment. Total fuel capacity is 7,000 gallons (26,495 liters).

The airplane has two Pratt & Whitney JT8D-219 engines, each rated at 21,000 pounds (9,526 kilograms) thrust. The engines are 2 percent more fuel efficient than the MD-82's JT8D-217 engines.

Maximum takeoff weight is 160,000 pounds (72,576 kilograms). Balanced field length at maximum takeoff weight is 8,380 feet (2,554 meters). Maximum level speed is 500 knots. Maximum cruising speed is 0.76 Mach. Range with 155 passengers and domestic fuel reserve is 2,502 nautical miles (4,634 kilometers). Maximum landing weight is 139,500 pounds (63,277 kilograms). Landing distance at maximum landing weight is 5,200 feet (1,585 meters).♦

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

when the accident airplane was landed by another flight crew at Puerto Vallarta about 1239.

Before departing from Puerto Vallarta at 1337, the accident flight crew selected the horizontal-stabilizer-trim system to seven degrees nose-up, which was the correct trim setting for takeoff.

"The horizontal stabilizer is mounted on top of the 18-foot-high [six-meter-high] vertical stabilizer; [the horizontal stabilizer and the vertical stabilizer] are connected by two hinges at the aft spar of the horizontal stabilizer and with a single jackscrew assembly at the front of the stabilizer in a T-tail configuration," the report said. "The horizontal stabilizer is about 40 feet [12 meters] long and comprises a center box and a left [outboard section] and a right outboard section. Each outboard section of the horizontal stabilizer has an elevator hinged to its trailing edge.

"Coarse pitch [adjustments] are achieved with elevator movement via mechanical linkage from the elevator-control tabs to the cockpit control columns. Finer adjustments to pitch are achieved by changing the angle of the entire horizontal stabilizer. The leading edge of the horizontal stabilizer is raised or lowered by the jackscrew assembly as the stabilizer's trailing edge pivots (rotates) about its hinge points.

"Movement of the horizontal stabilizer is provided by the jackscrew assembly, which consists of an acme screw and [an acme] nut, a torque tube inside the acme screw, two gearboxes, two trim motors (an alternate and a primary), and associated components and supports [see Figure 1, page 3].

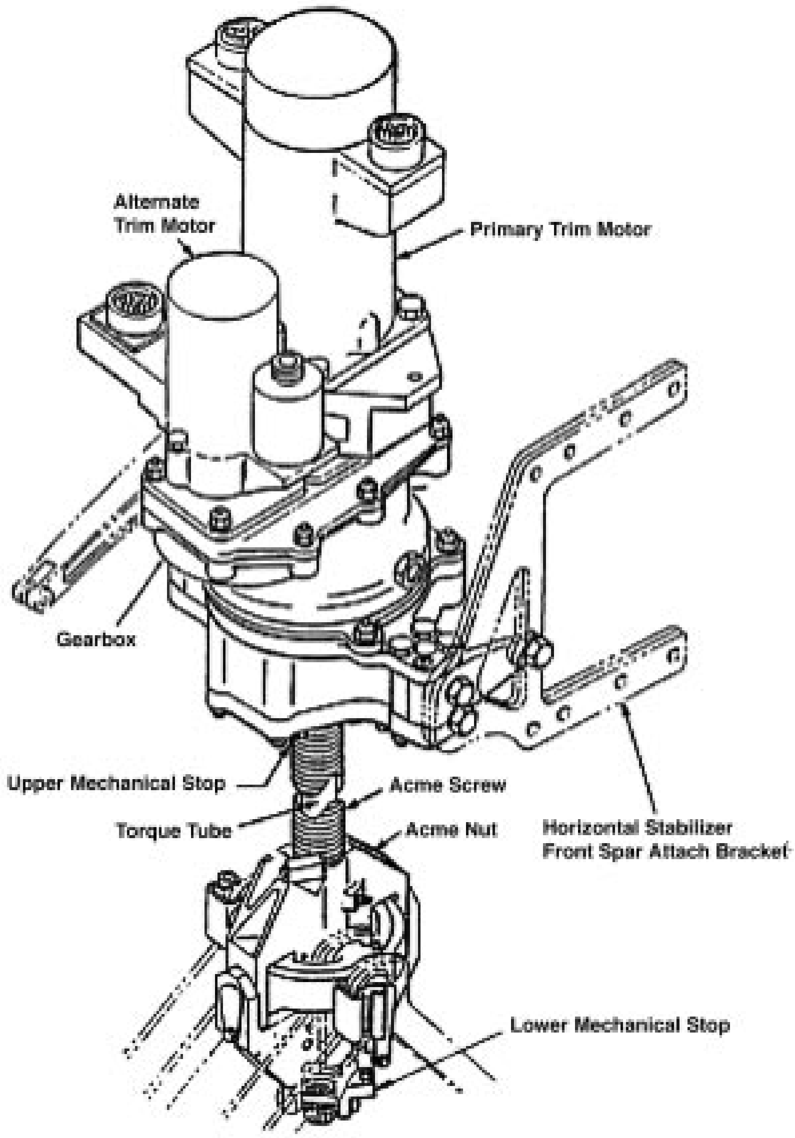
"The upper end of the jackscrew assembly is attached to the front spar of the horizontal stabilizer, and the lower end is threaded through the acme nut, which is attached to the vertical stabilizer with a gimbal ring and retaining pins. The acme screw and [acme] nut each have two threads that rotate in a spiral along their length.

"Movement of the horizontal stabilizer is commanded either automatically by the autopilot when it is engaged or manually by the flight crew — by depressing either set of dual trim switches (located on each control wheel), moving the dual longitudinal-trim handles on the center control pedestal or moving the dual alternate-trim-control switches on the center pedestal. Any of these commands activates one of the two electric motors that rotate the acme screw by applying torque to the titanium torque tube that is held fixed inside the acme screw."

The design limits for movement of the horizontal stabilizer on MD-80-series airplanes are 12.2 degrees leading-edge down (for airplane-nose-up trim) and 2.1 degrees leading-edge up (for nose-down trim).

"Electrical travel-limit shutoff switches (also known as electrical stops) stop the motors at the maximum limits of

McDonnell Douglas MD-83 Horizontal-stabilizer-trim System



Source: U.S. National Transportation Safety Board

Figure 1

travel," the report said. "The jackscrew also has upper and lower mechanical stops [attached] to the acme screw to stop screw rotation if the travel-limit shutoff switches malfunction."

The crew engaged the autopilot at 1340, during climb through 6,200 feet; the first officer was the pilot flying. At this time, horizontal-stabilizer trim was about two degrees nose-up.

FDR data indicated that the horizontal-stabilizer-trim-control system functioned normally until about 1350, when horizontal-stabilizer trim moved from 0.25 degree nose-down to 0.4 degree nose-down. This occurred during climb through about 23,400 feet at 331 knots indicated airspeed (KIAS). The horizontal stabilizer did not move again for about two hours and 20 minutes.

"This cessation of horizontal-stabilizer movement is not consistent with a typical MD-80 climb profile, which normally would require additional stabilizer movements to maintain trim," the report said. "Thus, as the accident airplane continued to climb above 23,400 feet without any horizontal-stabilizer movement, the autopilot would have attempted to achieve trim by continuing to add elevator input to compensate for the lack of movement of the horizontal stabilizer."

The report said that the flight crew likely conducted the "Stabilizer Inoperative" checklist and the "Runaway Stabilizer" emergency checklist, both of which are in the airline's *MD-80 Quick Reference Handbook* (QRH), during their initial attempts to correct the horizontal-stabilizer-control problem.

"Neither [checklist] required landing at the nearest suitable airport," the report said. "These checklist procedures were the only stabilizer-related checklist procedures contained in the QRH."

The report said that if the crew had decided to return to Puerto Vallarta, they would have had to either conduct an overweight landing at the airport or fly the airplane for about 45 minutes to reduce the fuel load sufficiently to meet maximum-landing-weight requirements.

"An overweight landing at [Puerto Vallarta] would have been appropriate if the flight crew had realized the potentially catastrophic nature of the trim anomaly," the report said. "In light of the absence of a checklist requirement to land as soon as possible and the circumstances confronting the flight crew, the flight crew's decision not to return to [Puerto Vallarta] immediately after recognizing the horizontal-stabilizer-trim-system malfunction was understandable."

At 1353, during climb through 28,557 feet at 296 KIAS, the autopilot was disengaged. The report said that the crew likely disengaged the autopilot after observing the out-of-trim-warning light.

"FDR information and airplane-performance calculations indicated that during the next seven minutes, the airplane continued to climb at a much slower rate," the report said. "The airplane was flown manually, using up to as much as 50 pounds [23 kilograms] of control-column-pulling force.

"After reaching level flight, the airplane was flown for about 24 minutes using approximately 30 pounds [14 kilograms] of pulling force at approximately 31,050 feet and 280 KIAS. The airspeed was then increased to 301 KIAS, and the airplane was flown for almost [82] minutes using about 10 pounds of pulling force."

Investigators could not determine whether the control-column-pulling force was applied by the first officer, alone, or by the first officer and the captain working together.

"The flight crew would have likely attempted to correct the problem by manually activating the primary or alternate trim systems to move the horizontal stabilizer," the report said. "However, the horizontal stabilizer remained at 0.4 degree nose-down, indicating that the flight crew was unable to manually command movement of the horizontal stabilizer."

At about 1521, the flight crew radioed airline maintenance personnel and airline dispatch personnel on a shared radio frequency to discuss the horizontal-stabilizer-trim problem and their decision to divert the flight to Los Angeles (California) International Airport (LAX). The report said that the crew's decision to divert the flight to LAX was "prudent and appropriate."

The transcript of information recorded by the cockpit voice recorder (CVR) begins at 1549 (about 30 minutes before the airplane struck the ocean). The transcript indicates that at 1550, someone at the airline's maintenance facility at the Seattle, Washington, airport (SEA) said, "Understand you're requesting diversion to L A [Los Angeles] for this discrepancy. Is there a specific reason you prefer L A over San Francisco?"

The captain said, "Well, a lot of times, it's windy and rainy and wet in San Francisco, and it seemed to me that a dry runway … where the wind is usually right down the runway seemed a little more reasonable."

About this time, the first officer asked the captain to move his seat forward so that he could check a panel that contained circuit breakers for the horizontal-stabilizer-trim system. The first officer then said, "I don't think there's anything beyond that we haven't checked."

The report said that at 1547 — after hand flying the airplane for almost two hours — the crew had engaged the autopilot. The crew disengaged the autopilot at 1549:56 and re-engaged the autopilot 19 seconds later. The CVR recorded no discussion between the pilots of why the autopilot was re-engaged.

The report said that the "Stabilizer Inoperative" checklist requires that the autopilot not be used if the primary trim-control system and the alternate trim-control system are inoperative.

"The flight crew should have known that both the alternate and the primary trim-control systems were inoperative," the report said. "Thus, the flight crew's use of the autopilot was contrary to company procedures."

After the accident, Boeing issued a flight operations bulletin for Douglas DC-9, MD-80/90 and Boeing 717 flight crews that included the following recommendations:

> If a horizontal-stabilizer-trim system malfunction is encountered, complete the flight crew operating manual (FCOM) checklist(s). Do not attempt additional actions beyond that contained in the checklist(s). If completing the checklist procedures does not result in an operable trim system, consider landing at the nearest suitable airport.

The report said that the information in the Boeing bulletin is "generally appropriate," but flight crews should not just consider landing at the nearest suitable airport if normal operation of the trim system is not restored after conducting the checklists.

"In such a case, the flight crew should always land at the nearest suitable airport, as expeditiously and safely as possible," the report said.

The report said, "Alaska Airlines dispatch personnel appear to have attempted to influence the flight crew to continue to San Francisco International Airport [SFO] instead of diverting to [LAX]."

At 1552, a dispatcher at the airline's SEA facility told the crew that weather conditions at SFO included surface winds from 180 degrees at six knots, nine statute miles (15 kilometers) visibility, a few clouds at 1,500 feet, a broken ceiling at 2,800 feet and an overcast at 3,400 feet.

"If you want to land at L A, of course, for safety reasons, we will do that," the dispatcher said. "We'll tell you, though, that if we land in L A, we'll be looking at probably an hour to an hour and a half. We have a major [air traffic control (ATC)] flow program going right now. That's for ATC back in San Francisco."

The captain said, "Boy, you put me in a spot here. I really didn't want to hear about the flow being the reason you're calling me [be]cause I'm concerned about overflying suitable airports."

The dispatcher said, "Well, we want to do what's safe, so if that's what you feel is safe, we just want to make sure you have all of the info[rmation]."

The first officer told the captain, "We might just ask if there's a ground-school instructor there available and discuss it with him … or a simulator instructor."

The captain told the dispatcher, "We're wondering if we can get some support out of the instructional force — instructors up there — if they got any ideas on us." The report said that the captain did not receive a response from the dispatcher.

The captain told the first officer, "Not that I want to go on about it, [but] it just blows me away [that] they think we're going to land [and] they're going to fix it. Now, they're worried about the flow. I'm sorry, this airplane isn't going to go anywhere for a while … so you know."

A flight attendant said, "So, they're trying to put pressure on you?"

The captain said, "Well, no, yeah … and, actually, it doesn't matter that much to us."

The captain asked the dispatcher for information on surface-wind conditions at LAX. The dispatcher said that the surface wind at LAX was from 260 degrees at nine knots.

The captain and first officer discussed surface-wind conditions and runways in use at SFO and at LAX. The report said that a landing at SFO would be conducted with a direct crosswind; a landing at LAX would be conducted with a "minimal" crosswind.

At 1556, the captain told the dispatcher, "A direct crosswind … is effectively no change in groundspeed. I got to tell you, when I look at it from a safety point, I think that something that lowers my groundspeed makes sense."

The dispatcher said, "That will mean LAX then for you."

The captain said, "I suspect that that's what we'll have to do. OK … my plan is [to] continue as if [we are] going to continue [to] San Francisco, get all that data, then begin our descent back into LAX, and at a lower altitude, we will configure and check the handling envelope before we proceed with the approach."

At 1558, someone at the airline's operations facility at LAX asked the captain for an estimated time of arrival. The captain said, "I'm going to put it at about thirty [minutes], thirty-five minutes. … The longer, the more fuel I burn off, the better I am. But I wonder if you can compute our current CG [center of gravity] based on the information we had at takeoff."

The captain was told that his radio transmission was broken, and he said, "You know what, I'll wait a minute. We'll be a little bit closer and that'll help everything." The captain then told the first officer that he would radio the LAX operations facility when they were closer to Los Angeles.

The first officer said, "We're ninety-four miles from L A now."

The pilots then listened to the automatic terminal information service (ATIS) broadcast for LAX. The information included surface winds from 230 degrees at eight knots, a few clouds at 2,800 feet, scattered clouds at 12,000 feet and an overcast ceiling at 20,000 feet. Instrument landing system (ILS) approaches were being conducted to Runway 24L and Runway 24R, and visual approaches were being conducted to all runways.

At 1602, the captain asked the airline's LAX operations facility for information about the surface winds at SFO. After being told that the surface winds at SFO were from 170 degrees at six knots, the captain said, "That's what I needed. We are coming in to see you."

The first officer provided information to the LAX operations facility to compute the airplane's CG.

At 1607, a maintenance technician at the airline's maintenance facility at LAX radioed the crew. He said, "Are you [the] guys with the horizontal [stabilizer] situation?"

The captain said yes, and the maintenance technician asked if they had selected the "suitcase handles" or the "pickle switches."

"'Suitcase handles' is a colloquial term for the longitudinal-trim handles located on the center control pedestal," the report said. "'Pickle switches' is a colloquial term for the trim switches located on the outboard side of each of the control wheels."

The captain said, "Yeah, we tried everything together. We've run just about everything. If you've got any hidden circuit breakers, we'd love to know about them."

The maintenance technician said that he would "look at the circuit-breaker guide just as a double check." He asked the captain if the alternate trim system was inoperative.

The captain said that the entire horizontal-stabilizer-trim system appeared to be jammed. He said that when the primary trim system was selected, the indicator for alternating-current (AC) electrical load indicated that the trim motor was "trying to run," and that when the alternate trim system was selected, "nothing happens."

The report said that when the primary horizontal-stabilizer-trim motor is engaged, the AC-load-meter indication normally rises ("spikes") to a maximum load indication; when the alternate horizontal-stabilizer-trim motor is engaged, the AC load meter shows no spike because the alternate motor requires significantly lower electrical current than the primary motor.

The maintenance technician said, "OK, you say you get a spike on the meter up there in the cockpit when you try to move [the horizontal stabilizer] with the primary, right?"

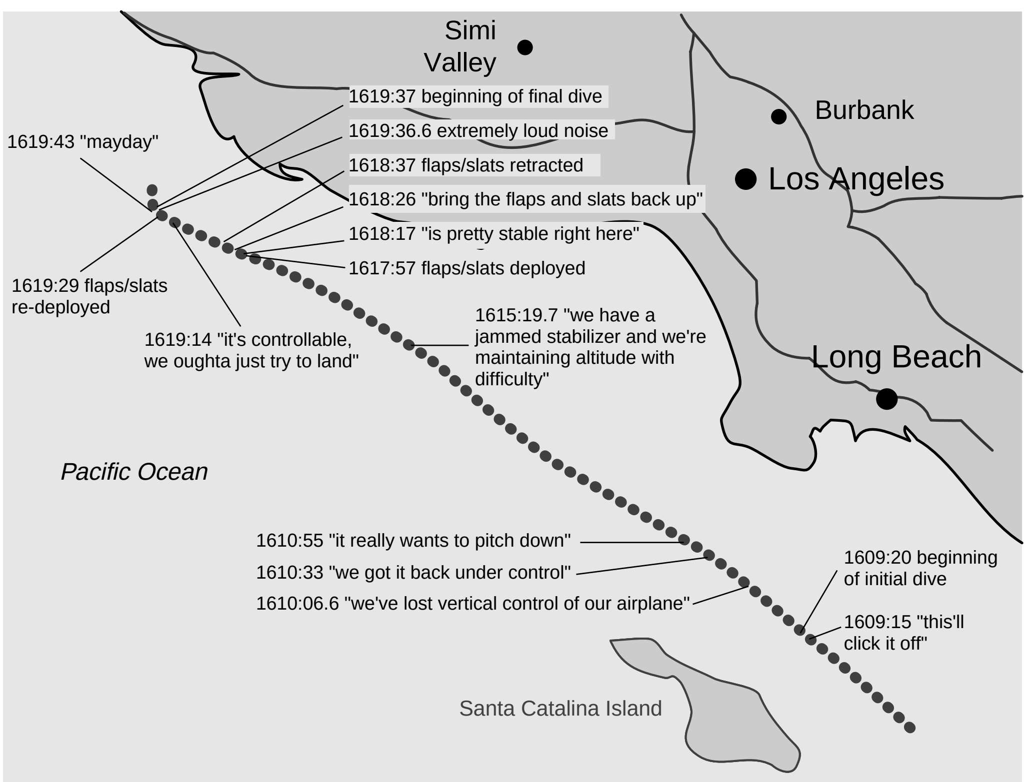
"Affirmative," the captain said. "We get a spike when we do the primary trim, but there's no appreciable change in the electrical [load] when we do the alternate."

The maintenance technician said, "OK, thank you, sir. See you here."

At 1609:13, the captain told the first officer, "Let's do that." The CVR then recorded the sound of a click and the captain saying, "This'll click it off." FDR data showed that the autopilot was disengaged. [Figure 2 shows the airplane's position at this time.]

"The captain [apparently] disconnected the autopilot when he activated the primary-trim-control system by using either the control-wheel trim switches, the longitudinal-trim handles, or both," the report said. "Consequently, although operation of

Flight Path of Alaska Airlines McDonnell Douglas MD-83 and Selected Cockpit Voice Recorder Data; Jan. 31, 2000



Source: U.S. National Transportation Safety Board

Figure 2

the primary trim motor as part of troubleshooting attempts earlier in the flight did not release the jam, the torque created by the primary trim motor when the captain activated the primary trim system at 1609:16 apparently provided enough force to overcome the jam between the acme nut and [acme] screw."

The horizontal stabilizer began to move from 0.4 degree nose-down to beyond 2.5 degrees nose-down, which is the maximum nose-down position that can be recorded by the FDR.

"As the [horizontal-stabilizer] jam was overcome, the acme screw was being pulled upward through the acme nut by aerodynamic loads, causing upward movement of the horizontal stabilizer, resulting in greater airplane-nose-down motion," the report said. "This upward pulling motion would have continued until the lower mechanical stop of the acme screw contacted the lower surface of the acme nut, preventing further upward motion of the horizontal stabilizer."

The airplane entered a dive at 1609:20 [Figure 3]. The CVR recorded the captain voicing an expletive and saying, "You got it?"

At 1609:55, the captain told the Los Angeles Center controller, "Alaska two sixty-one, we are in a dive here … and I've lost control, vertical pitch." The controller told the captain to repeat the message. The captain said, "We're out of twenty-six thousand feet. We are in a vertical dive … not a dive yet … but we've lost vertical control of our airplane."

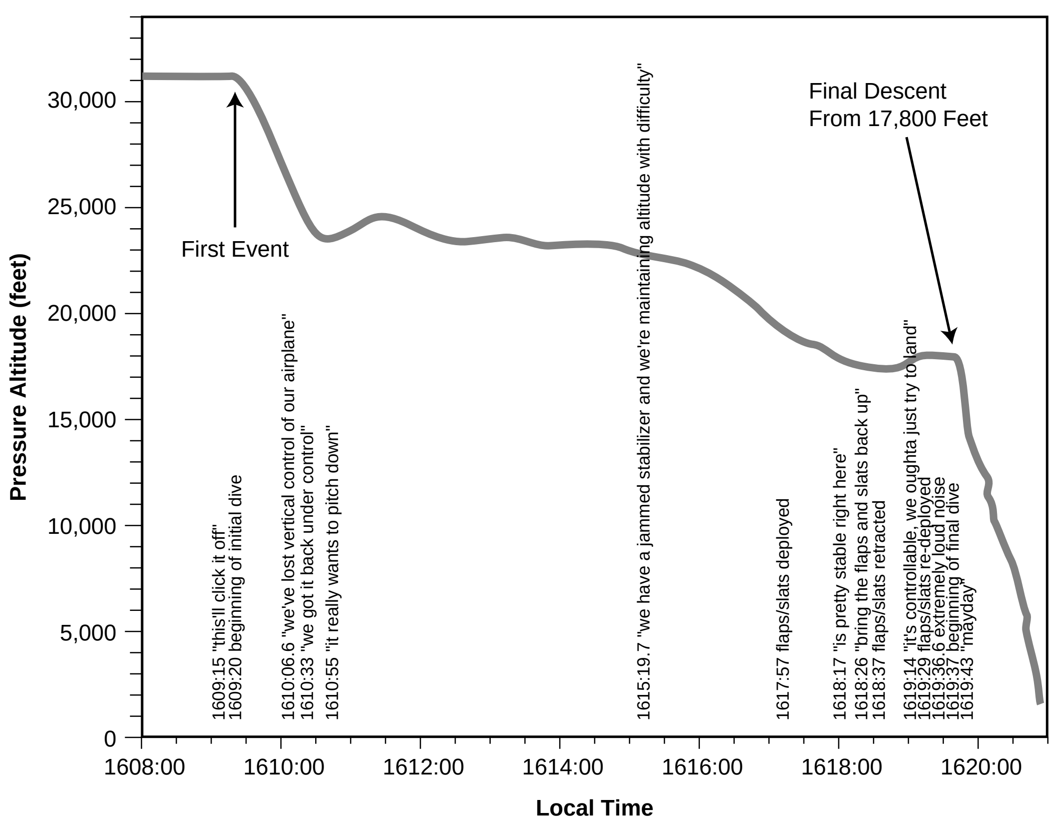
The overspeed warning sounded for 33 seconds during the dive. Airspeed was about 322 KIAS as the airplane descended through 29,450 feet. The report said that the crew deployed the speed brakes, likely in an attempt to reduce the airplane's rapidly increasing airspeed. Airspeed continued to increase to 353 KIAS.

The captain told the first officer, "Just help me. Once we get the speed slowed, maybe we'll be OK."

The report said that airplane-performance calculations indicated that between 130 pounds and 140 pounds (59 kilograms and 64 kilograms) of pulling force on the control columns was required to recover from the dive.

At 1610:28, the captain told the controller, "We're at twenty-three seven [23,700 feet], request … yeah, we got it back under control."

Vertical Flight Path of Alaska Airlines McDonnell Douglas MD-83 and Selected Cockpit Voice Recorder Data; Jan. 31, 2000



Source: U.S. National Transportation Safety Board

Figure 3

The first officer said, "No we don't … OK."

"OK," the captain said.

"Let's take the speed brakes off," the first officer said.

"No, leave them there," the captain said. "It seems to be helping. … OK, it really wants to pitch down."

At 1611:04, the controller said, "Alaska two sixty-one, say your condition."

The captain said, "Two sixty-one, we are at twenty-four thousand feet, kind of stabilized. We're slowing here, and we're going to do a little troubleshooting. Can you give me [an altitude] block between twenty and twenty-five?"

"Alaska two sixty-one, maintain block altitude flight level two zero zero through flight level two five zero," the controller said.

At 1611:13, the speed brakes were stowed. Airspeed had decreased to 262 KIAS, and the crew was maintaining level flight at about 24,400 feet. After the speed brakes were stowed, airspeed increased gradually to 335 KIAS over the next five minutes.

At 1611:33, the first officer said, "How hard is it?"

The captain said, "I don't know. My adrenaline's going. It was really tough there for a while."

"Whatever we did is no good," the first officer said. "Don't do that again."

"Yeah," the captain said. "No, it went down. It went to full nose-down."

"It's a lot worse than it was?" the first officer said.

"Yeah, we're in much worse shape now," the captain said. "I think it's at the stop, full stop, and I'm thinking … can it go any worse, but it probably can. But when we slowed down … Let's slow it. Let's get down to two hundred knots and see what happens."

"We have to put the slats out and everything," the first officer said. "Flaps and slats."

"Well, we'll wait," the captain said. "OK, you got it for a second?"

The first officer said "yeah."

At 1612:33, the captain radioed the airline's maintenance facility at LAX. "We did both the pickle switch and the suitcase handles, and it ran away full-nose-trim-down. And now we're in a pinch. … We're worse than we were. … We went to full nose-down, and I'm afraid to try it [the horizontal-stabilizer trim system] again to see if we can get it to go in the other direction."

A maintenance technician said, "OK. Well, your discretion. If you want to try it, that's OK with me; if not, that's fine. We'll see you at the gate."

The report said that at this time, about 120 pounds (54 kilograms) of control-pulling force was required to maintain level flight at about 24,400 feet.

The first officer said, "It … went in reverse? When you pulled back, it went forward?"

The captain said, "I went tab down … and it should have come back; instead, it went the other way. … What do you think? You want to try it or not?"

"No," the first officer said. "Boy, I don't know."

"It's up to you, man," the captain said. "I like where we're going, out over the water. … I don't like going this fast, though."

"We better talk to the people in the back there," the first officer said.

The captain then made a public-address announcement. "Folks, we have had a flight-control problem up front here," he said. "We're working it. That's Los Angeles off to the right there. That's where we're intending to go. We're pretty busy up here working this situation. I don't anticipate any big problems once we get a couple of subsystems on the line. But we will be going into L A X, and I'd anticipate us parking there in about twenty to thirty minutes."

At 1614:44, the speed brakes were deployed, and airspeed began to decrease.

The captain told the first officer, "Let's put the power where it'll be for … landing. You buy that? Slow it down and see what happens."

The controller told the crew to change to a different radio frequency for Los Angeles Center. The first officer acknowledged the controller's instruction. The captain told the first officer, "I got the yoke."

The first officer changed radio frequencies and told the controller, "We're with you … at twenty-two five [22,500 feet]. We have a jammed stabilizer, and we're maintaining altitude with difficulty. But we can maintain altitude, we think. Our intention is to land at Los Angeles."

The controller cleared the crew to fly the airplane directly to Santa Monica and then directly to Los Angeles. The controller said, "You want lower now, or what do you want to do, sir?"

The captain told the first officer, "Let me have it." He then told the controller, "I need to get down [to about 10,000 feet], change my configuration, make sure I can control the jet; and I'd like to do that out here over the bay, if I may." The controller told the captain to stand by.

The first officer told the captain that they should check the airplane's control characteristics at their current altitude, rather than at 10,000 feet. The captain said that the air is denser at 10,000 feet than at their current altitude. He said, "You know what I'm saying?"

The first officer said "yeah."

At 1616:32, the controller told the crew to fly a heading of 280 degrees, descend to 17,000 feet and change to a different radio frequency for Los Angeles Center. The first officer acknowledged the instructions and obtained the current altimeter setting.

The crew made no further radio transmissions.

At 1617:01, the captain told a flight attendant, "I need everything picked up and everybody strapped down, because I'm going to unload the airplane and see if we can regain control."

"OK," the flight attendant said. "We had like a big bang back there."

"Yeah, I heard it," the captain said. "The stab[ilizer] trim, I think it … I think the stab trim thing is broke. … I need you, everybody, strapped in now, dear, … because I'm going to release the back pressure and see if I can get it … back."

The first officer said, "I don't think you want any more speed brakes do you?" The captain said no. The speed brakes were stowed at 1617:50. The airplane was level at 18,000 feet, and airspeed had decreased to 252 KIAS.

The first officer said, "He [the controller] wants us to maintain seventeen [thousand feet]."

"OK," the captain said. "I need help with this here." The captain then told the first officer to extend the wing leading-edge slats. At 1617:56, the CVR recorded a sound similar to movement of the slat/flap handle, and the FDR recorded the extension of the slats. At the time, the airplane was descending through 17,800 feet.

"I'm test flying now," the captain said.

"How does it feel?" the first officer said.

"It's wanting to pitch over more on you," the captain said.

"Try flaps?" the first officer said. "Fifteen, eleven?"

"Let's go to [flaps position] eleven," the captain said.

At 1618:07, the CVR recorded a sound similar to movement of the slat/flap handle.

The first officer said that they should "get some power on."

The captain said that the airplane was "pretty stable right here" at their current airspeed, 250 KIAS, and that "we got to get down to a hundred and eighty [KIAS]." He then told the first officer to retract the slats and flaps. The CVR recorded a sound similar to movement of the slat/flap handle.

During the 50 seconds after the slats and flaps were retracted, indicated airspeed increased to 270 KIAS, and the airplane climbed from about 17,400 feet to 17,900 feet.

At 1618:47, the captain said, "What I want to do … is get the nose up … and then let the nose fall through and see if we can stab it when it's unloaded."

"You mean use this again?" the first officer said. "I don't think we should … if it can fly."

The report said that the first officer's statements indicate that the captain might have intended to use the primary trim system after reducing aerodynamic forces on the horizontal stabilizer.

"It's on the stop now," the captain said. "It's on the stop."

"Well, not according to that, it's not," the first officer said. "[There] might be mechanical damage, too. I think if it's controllable, we ought to just try to land it."

"You think so?" the captain said. "OK, let's head for L A."

The report said that at 1619:21, the CVR recorded the first of at least four thumps. FDR data indicated an increase in horizontal-stabilizer position.

"Although the horizontal-stabilizer position had already exceeded the maximum position capable of being sensed and recorded by the FDR, the FDR nonetheless indicated an increase in the horizontal-stabilizer position at the time of the faint thump," the report said. "This increase was the first horizontal stabilizer movement since the one that precipitated the initial dive about 10 minutes earlier."

Investigators determined that the additional movement of the horizontal stabilizer likely resulted from the fracture of the acme-screw torque tube.

"You feel that?" the first officer said.

"Yeah," the captain said. "OK, give me sl[ats]."

At 1619:32, the CVR recorded two clicks similar to movement of the slat/flap handle. FDR data recorded four seconds later indicated that the flaps and the slats were extending when the

CVR recorded an extremely loud noise, an increase in background noise and sound similar to loose articles moving around the flight deck. The report said that the extremely loud noise likely resulted from the fracture of the vertical-stabilizer-tip-fairing brackets.

"Immediately thereafter, the airplane began its final dive," the report said. "At the time of this pitchover, [ATC] radar detected several small primary returns, consistent with parts of the vertical stabilizer's tip fairing being torn from the airplane as the fairing brackets broke, which would have allowed the horizontal stabilizer to move well beyond the 3.6-degree airplane-nose-down position it was being held at by the brackets.

"Therefore, the extremely loud noise recorded on the CVR … was likely made as the fairing brackets failed and caused the loss of the tip fairing and structural deformation of the tail under flight loads, resulting in local aerodynamic disturbances."

The airplane began to roll left. A few seconds later, at 1619:43, the CVR recorded the first officer saying "mayday"; the statement was not transmitted by radio.

FDR data indicated that at this time, the airplane had rolled inverted and was descending through 16,420 feet with an indicated airspeed of 208 knots.

At 1619:49, the captain said, "Push and roll. Push and roll. OK, we are inverted … and now, we got to get it … Kick. Push, push, push. Push the blue side up. Push."

"OK, I'm pushing," the first officer said.

"OK, now let's kick rudder," the captain said. "Left rudder. Left rudder."

"I can't reach it," the first officer said.

"OK, right rudder," the captain said. "Right rudder."

The airplane remained in a nearly inverted attitude, with nose-down pitch oscillations occurring.

At 1620:25, the captain said, "Are we flying? We're flying. We're flying. Tell them what we're doing. … Got to get it over again. … At least upside-down, we're flying."

At 1620:49, the CVR began recording sounds similar to engine compressor stalls and a sound similar to an engine spooling down.

At 1620:54, the captain said "speed brakes."

"Got it," the first officer said.

At 1620:56, the captain said, "Ah, here we go." The CVR ceased recording one second later.

The report said, "Analysis of the structural damage and FDR data indicated that the airplane was nearly inverted and was in a steep nose-down, right-wing-low attitude when it impacted the water, which is consistent with uncontrolled flight."

The airplane was destroyed on impact.

"No occupiable space remained intact," the report said. "The [coroner's] report stated that all of the accident airplane's occupants died as a result of blunt-force-impact trauma."

During examination of the wreckage, acme-nut-thread remnants were found wrapped around the acme screw (see photo, page 11).

"The condition of the recovered acme-nut-thread remnants indicated that approximately 90 percent of the thread thickness had worn away before the remainder of the threads sheared off," the report said.

Corrosion pitting and red rust were found on most of the acme screw.

"Large areas of the acme screw were also found covered by white deposits, which chemical analysis determined were consistent with corrosion debris from the magnesium gearbox case attached to the top of the acme-screw assembly," the report said.

No grease was found on the threads of the "working region" of the acme screw — that is, the section of the acme screw that normally comes in contact with the acme nut.

"Laboratory examinations found small flakes of dried and hardened grease attached to some of the thread remnants in this region," the report said. "The acme screw's lower threads (which are outside of the working region) were found partially packed with a mixture consistent with sand and grease. … Parts of the acme screw's upper six [threads] to eight threads had an oily sheen, and small deposits of greaselike material were found between the threads."

Examination of the acme nut showed that most of the threads were missing.

"The thread area on the inside diameter of the acme nut showed a relatively smooth, flat surface, with only small ridges of the acme thread remaining," the report said.

The report said that the design of the jackscrew assembly did not include a "fail-safe mechanism to prevent the catastrophic effects of total acme-nut thread loss."

MD-80-series airplanes, MD-90-series airplanes and the Boeing 717[1] are derivatives of the Douglas DC-9, which was certified in 1965 under U.S. Civil Aeronautics Regulations (CARs) 4b. The MD-80 was certified in 1980 under U.S. Federal Aviation Regulations (FARs) Part 25.

Remnants of thread material sheared from the acme nut can be seen wrapped around this approximately 17-inch (43-centimeter) section of the acme screw. (NTSB photo)

"However, systems that were similar to or that did not change significantly from the earlier DC-9 models, such as the longitudinal-trim-control system, were not required to be recertified under Part 25," the report said. "Therefore, [CARs] 4b remained the certification basis for those parts."

The report said that the design of the longitudinal-trim-control system included no provision for redundancy following complete loss of threads in the acme nut.

"The acme nut was designed with a softer material than the acme screw, and its threads were designed to wear," the report said. "Acme-nut threads are made of an aluminum-bronze alloy … . The acme-screw threads are made of case-hardened steel."

Figure 4 (page 12) shows the stages of acme-nut-thread wear to the point of thread failure.

The design service life of the DC-9 jackscrew assembly was 30,000 flight hours. Excessive wear found in several jackscrew assemblies prompted Douglas Aircraft Co. in 1966 to recommend periodic "on-wing end-play checks," in which a maintenance technician uses a special tool (a restraining fixture) to reverse the load on the acme screw and a dial indicator to record the resulting vertical movement of the acme screw. The end-play measurement indicates the amount of gap that exists between the acme-nut threads and the acme-screw threads — and, thus, the amount of acme-nut-thread wear.

"The only portion of the jackscrew assembly that wears significantly is the aluminum-bronze acme nut," the report said.

The on-wing procedure allows acme-nut wear to be monitored without removing the jackscrew assembly from the airplane. Douglas recommended that acme nuts be replaced when end-play measurement exceeds 0.04 inch (0.10 centimeter).

End-play checks originally were recommended by Douglas every 3,600 flight hours during maintenance "C" checks. In 1996, the recommended interval was changed to 7,200 flight hours or 30 months, whichever comes first.

At the time of the accident, Alaska Airlines conducted end-play checks every 30 months (i.e., during every other maintenance "C" check). The report said that this interval corresponded to about 9,550 flight hours, based on airplane-utilization rates.

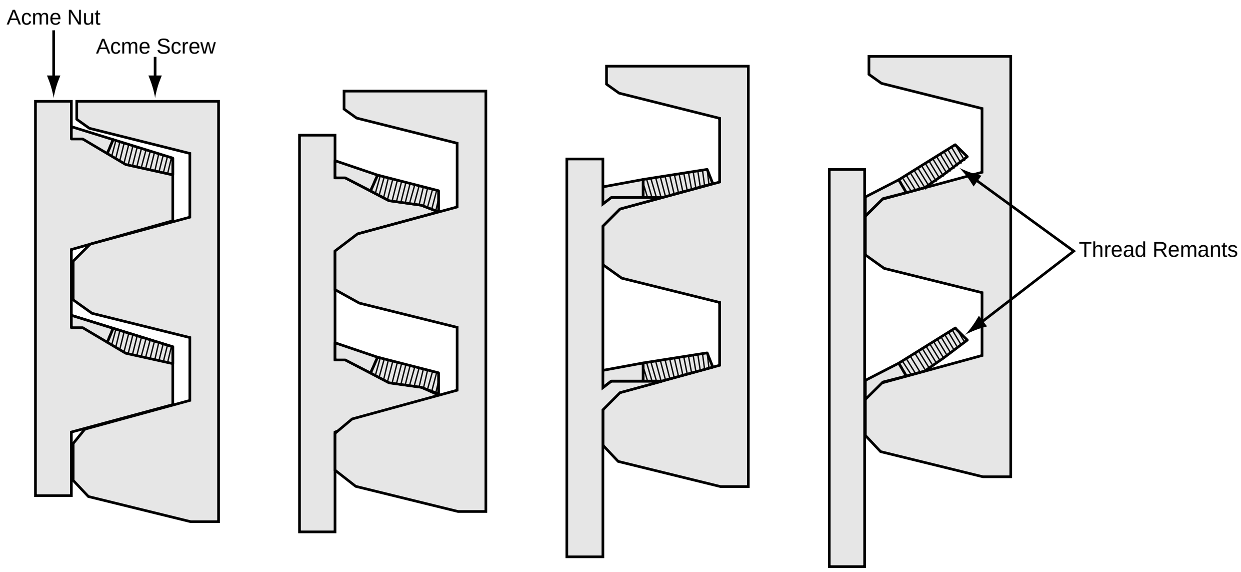
The report said that although the airline's 30-month end-play-check interval complied with the manufacturer's recommended calendar-time limit, the resulting 9,550-flight-hour interval far exceeded the manufacturer's recommended flight-hour interval.

"Alaska Airlines' extension of the end-play-check interval and the [FAA's] approval of that extension allowed the accident acme-nut threads to wear to failure without the opportunity for detection," the report said. "[The] end-play-check-interval extension should have been, but was not, supported by adequate technical data to demonstrate that the extension would not present a potential hazard."

Douglas originally recommended lubrication of jackscrew assemblies every 600 flight hours to 900 flight hours. In 1996, the recommended interval was changed; jackscrew-assembly lubrication was recommended during maintenance "C" checks conducted every 3,600 flight hours or 15 months, whichever comes first.

At the time of the accident, Alaska Airlines lubricated jackscrew assemblies every eight months. The report said that, based on airplane-utilization rates, eight months corresponded to about 2,550 flight hours.

Stages of Acme-nut-thread Wear to Point of Bending-induced Shear



Source: U.S. National Transportation Safety Board

Figure 4

During a maintenance "C" check performed on the accident airplane on Sept. 26, 1997, an end-play check was performed and the jackscrew assembly was lubricated. The end-play measurement was 0.033 inch (0.084 centimeter). The airplane had accumulated 17,699 flight hours.

Tests indicated that the restraining fixtures fabricated by Alaska Airlines to conduct end-play checks could yield measurements that were lower than measurements obtained with restraining fixtures manufactured by Boeing.

"Therefore, it is possible that the … 0.033-inch end-play measurement obtained during the accident airplane's September 1997 end-play check were less than the actual end play and that the accident jackscrew assembly in fact exceeded the 0.04-inch end-play-measurement limit," the report said.

No further end-play checks were performed on the accident airplane's jackscrew assembly. The assembly was lubricated in June 1998, in January 1999 (during a maintenance "C" check, when the airplane had accumulated 22,407 flight hours) and in September 1999.

The report said that Mobilgrease 28, which conforms to the manufacturer's specifications for grease (MIL-G-81322), was used during the jackscrew lubrication in September 1997. Aeroshell 33 grease was used during the subsequent lubrications of the jackscrew.

In an effort to standardize and reduce the number of different greases used during maintenance, Alaska Airlines in 1996 asked McDonnell Douglas if Aeroshell 33 could be used on certain MD-80 components, including the jackscrew assembly. After conducting laboratory tests, the manufacturer in September 1997 told the airline that it had "no technical objection to the use of [Aeroshell 33] grease in place of MIL-G-81322 grease" on MD-80 components not subjected to temperatures in excess of 250 degrees Fahrenheit (121 degrees Celsius).

The manufacturer told the airline that "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. 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."

Boeing told investigators that McDonnell Douglas never completed the testing of Aeroshell 33.

In March 2000, FAA asked Alaska Airlines for documents supporting the change from Mobilgrease 28 to Aeroshell 33 to grease the jackscrew assembly. In April 2000, FAA told the airline that the documents did not support the change and disapproved the use of Aeroshell 33 as a substitute for Mobilgrease 28.

Post-accident tests conducted for NTSB by laboratories at Rensselaer Polytechnic Institute in Troy, New York, U.S., and by Battelle Memorial Institute in Columbus, Ohio, U.S., included more than 50 wear tests using Mobilgrease 28 and Aeroshell 33 on a steel ring sliding on an aluminum-bronze block, simulating an operational jackscrew.

"The results of the wear tests showed that, in all ranges of contact pressure, lower wear rates were generated when Aeroshell 33 was used than when Mobilgrease 28 was used," the report said. "Additionally, the effects of contamination, aging and subzero-temperature exposure were determined to have little effect on the lubricating effectiveness of Aeroshell 33. Only the tests run without any lubrication generated wear rates significantly higher than those generated when Mobilgrease 28 was used."

The report said that the airline's use of Aeroshell 33 to lubricate the jackscrew assembly was not a factor in the excessive wear of the acme-nut threads in the accident airplane; insufficient lubrication was a factor.

"There was no effective lubrication on the acme screw and [acme] nut interface at the time of the Alaska Airlines Flight 261 accident," the report said. "The excessive and accelerated wear of the accident jackscrew assembly acme-nut threads was the result of insufficient lubrication, which was directly causal to the … accident."

Investigators found that maintenance technicians use various methods for jackscrew lubrication. Laboratory demonstrations showed that application of grease over all exposed threads and then cycling the trim system several times distributes grease on the acme screw more evenly and adequately than applying grease only through the acme-nut grease fitting and cycling the trim system several times. The report said that removing used grease from the acme screw before applying fresh grease increases the effectiveness of the lubrication.

On Feb. 11, 2000, FAA issued Airworthiness Directive (AD) 2000-03-51 to operators of DC-9, MD-88, MD-90-30 and B-717-200 airplanes. The AD was prompted by reports of metal shavings found near the jackscrew assemblies in two airplanes. The AD included requirements for visual inspections for metal shavings and metal flakes in the lubricating grease on jackscrew assemblies and in areas near jackscrew assemblies, and for jackscrew corrosion, pitting or "distress."

"In addition, AD 2000-03-51 required an inspection of the lubrication of the jackscrew assembly, an inspection of the acme screw and [acme] nut upper and lower mechanical stops, testing of the horizontal-stabilizer-shutoff control, and the performance of end-play checks … at intervals not to exceed 2,000 flight hours," the report said.

The report said that the 2,000-flight-hour interval required by the AD may not be adequate in situations involving higher-than-expected wear.

On July 28, 2000, FAA issued AD 2000-15-15, which included the requirements of AD 2000-03-51 and also required operators to inspect for metallic particles in jackscrew lubricating grease.

During its investigation of the accident, NTSB made the following recommendations to FAA:

- "Require [Boeing] to revise the lubrication procedure for the horizontal-stabilizer-trim system of [DC-9, MD-80/90 and B-717] series airplanes to minimize the probability of inadequate lubrication. (A-01-41)"

  [In response to recommendation A-01-41, FAA on June 14, 2002, told NTSB that it was working with Boeing to "rewrite the lubrication procedures to the optimal standard" and was "evaluating the necessity of adding another task to perform a detailed inspection of the lubricant at a 'C' (maintenance) check interval for indications of metal shavings."[2]]

- "Require [Boeing] to revise the end-play-check procedure for the horizontal-stabilizer-trim system of [DC-9, MD-80/90 and B-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 [wear] 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)"

  [In response to recommendation A-01-42, FAA on Dec. 12, 2001, told NTSB that it "asked Boeing to conduct a study to validate the revised procedure empirically against an appropriate physical standard of actual acme screw (wear) and acme nut wear. The study will also establish procedures that produce a measurement that is reliable when conducted on-wing. Boeing anticipates that a prototype of an improved end-play-check procedure and an improved end-play-check kit will be available within 12 months. The FAA further estimates that the on-wing reliability of the improved end-play-check procedure could be validated within an additional 12–18 months to provide a statistically significant sample for evaluation."[3] (FAA has evaluated Boeing's improved end-play-check procedure and has determined that the procedure is adequate.)[4]]

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

- "Require maintenance personnel who inspect the horizontal-stabilizer-trim system of [DC-9, MD-80/90 and B-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)"

  [In response to recommendation A-01-43 and recommendation A-02-44, FAA on Dec. 12, 2001, told NTSB that current requirements of FARs Part 121.375

"adequately address maintenance-training programs," that Advisory Circular (AC) 120-16C, *Continuous Airworthiness Maintenance Programs*, was being revised "to expand the intent of the requirement for maintenance-training programs" and that current requirements of Part 65.81 and Part 65.103 "adequately address the inspection requirements for maintenance personnel and repairmen."[5] (As of Feb. 11, 2003, FAA had not completed its revision of AC 120-16C.)[6]]

- "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 [to] obtain approval of the proposed changes from the principal maintenance inspector and concurrence from the applicable FAA 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)"

  [In response to recommendation A-01-45 and recommendation A-01-46, FAA on July 29, 2002, told NTSB that it issued Flight Standards Information for Airworthiness (FSAW) 02-02, *The Potential Adverse Effects of Grease Substitution*, "which provides inspectors with guidance on processing an operator's proposed substitution of a lubricant or a lubrication-application-method change" and that it revised Order 8300.10, *Airworthiness Inspector's Handbook*, "to state that if there is any doubt as to the soundness of the request, the aviation safety inspector should coordinate the request with the appropriate aircraft-certification office."[7]]

- "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)"

  [In response to recommendation A-01-47 and recommendation A-01-48, FAA on June 14, 2002, told NTSB that an FAA/industry forum to discuss the issues was scheduled to be held Sept. 12–13, 2001, but, because of the terrorist attacks in the United States on Sept. 11, 2001, the forum was rescheduled for Jan. 30–31, 2002.[8] (The FAA/industry forum subsequently was rescheduled and was conducted June 26–27, 2002, in Seattle, Washington, U.S.)[9]]

After NTSB completed the accident investigation, the board on Jan. 8, 2003, made the following recommendations to FAA (As of Feb. 11, 2003, NTSB had not received responses from FAA about the recommendations):

- "Issue a flight standards information bulletin directing air carriers to instruct pilots that in the event of an inoperative or malfunctioning flight control system, if the airplane is controllable, they should complete only the applicable checklist procedures and should not attempt any corrective actions beyond those specified. In particular, in the event of an inoperative or malfunctioning horizontal-stabilizer-trim-control system, after a final determination has been made in accordance with the applicable checklist that both the primary and alternate trim systems are inoperative, neither the primary nor the alternate trim motor should be activated, either by engaging the autopilot or using any other trim-control switch or handle. Pilots should further be instructed that if checklist procedures are not effective, they should land at the nearest suitable airport. (A-02-36);

- "Direct all certificate-management offices to instruct inspectors to conduct surveillance of airline-dispatch [personnel] and maintenance-control personnel to ensure that their training and operations directives provide appropriate dispatch support to pilots who are experiencing a malfunction threatening safety of flight and instruct them to refrain from suggesting continued flight in the interest of airline flight scheduling. (A-02-37);

- "As part of the response to safety recommendation A-01-41, require operators of [DC-9, MD-80/90 and B-717] series airplanes to remove degraded grease from the jackscrew assembly acme screw and flush degraded grease and particulates from the acme nut before applying fresh grease. (A-02-38);

- "As part of the response to safety recommendation A-01-41, require operators of [DC-9, MD-80/90 and B-717] series airplanes, in coordination with Boeing, to increase the size of the access panels that are used to accomplish the jackscrew-assembly-lubrication procedure. (A-02-39);

- "Establish the jackscrew-assembly-lubrication procedure as a required inspection item that must have an inspector's signoff before the task can be considered complete. (A-02-40);

- “Review all existing maintenance intervals for tasks that could affect critical aircraft components and identify those that have been extended without adequate engineering justification in the form of technical data and analysis demonstrating that the extended interval will not present any increased risk and require modifications of those intervals to ensure that they take into account assumptions made by the original designers, are supported by adequate technical data and analysis, and include an appropriate safety margin that takes into account the possibility of missed or inadequate accomplishment of the maintenance task. In conducting this review, [FAA] should also consider original intervals recommended or established for new aircraft models that are derivatives of earlier models and, if the aircraft component and the task are substantially the same and the recommended interval for the new model is greater than that recommended for the earlier model, treat such original intervals for the derivative model as ‘extended’ intervals. (A-02-41);

- “Conduct a systematic industrywide evaluation and issue a report on the process by which manufacturers recommend and airlines establish and revise maintenance-task intervals and make changes to the process to ensure that, in the future, intervals for each task take into account assumptions made by the original designers, are supported by adequate technical data and analysis, and include an appropriate safety margin that takes into account the possibility of missed or inadequate accomplishment of the maintenance task. (A-02-42);

- “Require operators to supply the [FAA], before the implementation of any changes in maintenance-task intervals that could affect critical aircraft components, technical data and analysis for each task demonstrating that none of the proposed changes will present any potential hazards, and obtain written approval of the proposed changes from the principal maintenance inspector and written concurrence from the appropriate FAA aircraft certification office. (A-02-43);

- “Pending the incorporation of a fail-safe mechanism in the design of the [DC-9, MD-80/90 and B-717] horizontal-stabilizer-jackscrew assembly, as recommended in safety recommendation A-02-49, establish an end-play-check interval that accounts for the possibility of higher-than-expected wear rates and measurement error in estimating acme-nut-thread wear and provides for at least two opportunities to detect excessive wear before a potentially catastrophic wear condition becomes possible. (A-02-44);

- “Require operators to permanently track end-play measures according to airplane registration number and jackscrew assembly serial number, calculate and record average wear rates for each airplane based on end-play measurements and flight times, and develop and implement a program to analyze these data to identify and determine the cause of excessive or unexpected wear rates, trends or anomalies. [FAA] should also require operators to report this information to FAA for use in determining and evaluating an appropriate end-play-check interval. (A-02-45);

- “Require that maintenance facilities that overhaul jackscrew assemblies record and inform customers of an overhauled jackscrew assembly’s end-play measurement. (A-02-46);

- “Require operators to measure and record the on-wing end-play measurement whenever a jackscrew assembly is replaced. (A-02-47);

- “Require that maintenance facilities that overhaul [DC-9, MD-80/90 and B-717] series airplanes’ jackscrew assemblies obtain specific authorization to perform such overhauls, predicated on demonstrating that they possess the necessary capability, documentation and equipment for the task, and that they have procedures in place to perform and document the detailed steps that must be followed to properly accomplish the end-play-check procedure and lubrication of the jackscrew assembly, including specification of appropriate tools and grease types; perform and document the appropriate steps for verifying that the proper acme-screw-thread-surface finish has been applied; and ensure that appropriate packing procedures are followed for all returned overhauled jackscrew assemblies, regardless of whether the assembly has been designated for storage or shipping. (A-02-48);

- “Conduct a systematic engineering review to identify means to eliminate the catastrophic effects of total acme-nut-thread failure in the horizontal-stabilizer-trim system jackscrew assembly in [DC-9, MD-80/90 and B-717] series airplanes and require, if practicable, that such fail-safe mechanisms be incorporated in the design of all existing and future DC-9, MD-80/90 and [B-]717 series airplanes and their derivatives; evaluate the horizontal-stabilizer-trim systems of all other transport category airplanes to identify any designs that have a catastrophic single-point failure mode; and, for any such system, identify means to eliminate the catastrophic effects of that single-point failure mode and, if practicable, require that such fail-safe mechanisms be incorporated in the design of all existing and future airplanes that are equipped with such horizontal-stabilizer-trim systems. (A-02-49);

- “Modify the certification regulations, policies or procedures to ensure that new horizontal-stabilizer-trim-control system designs are not certified if they have a single-point catastrophic failure mode, regardless of whether any element of that system is considered structure rather than system or is otherwise considered exempt from certification standards for systems. (A-02-50); [and,]

- "Review and revise aircraft-certification regulations and associated guidance applicable to the certification of transport category airplanes to ensure that wear-related failures are fully considered and addressed so that, to the maximum extent possible, they will not be catastrophic. (A-02-51)"♦

[FSF editorial note: This article, except where specifically noted, is based on U.S. National Transportation Safety Board (NTSB) Aircraft Accident Report NTSB/AAR-02/01: *Loss of Control and Impact With Pacific Ocean; Alaska Airlines Flight 261, McDonnell Douglas MD-83, N963AS; About 2.7 Miles North of Anacapa Island, California; January 31, 2000* (236 pages with appendixes and illustrations) and NTSB Safety Recommendation A-02-36 through -51 (24 pages).]

Notes

1. The Boeing Co. and McDonnell Douglas Corp. merged in 1997 under the Boeing name. The MD-95 was renamed the Boeing 717.

2. U.S. Federal Aviation Administration (FAA). *Brief Report for NTSB Safety Recommendations*, A-01-41. <nasdac.faa.gov>.

3. FAA. *Brief Report for NTSB Safety Recommendations*, A-01-42. <nasdac.faa.gov>.

4. Huettner, Gene; manager, FAA Aircraft Evaluation Group, Long Beach, California, U.S. Telephone interview by Lacagnina, Mark. Alexandria, Virginia, U.S., 12 February 2003. Flight Safety Foundation, Alexandria, Virginia, U.S.

5. FAA. *Brief Report for NTSB Safety Recommendations*, A-01-43 and A-01-44. <nasdac.faa.gov>.

6. Hinton, Jeane; manager, FAA Program Management and Information Branch. Telephone interview by Lacagnina, Mark. Alexandria, Virginia, U.S., 11 February 2003. Flight Safety Foundation, Alexandria, Virginia, U.S.

7. FAA. *Brief Report for NTSB Safety Recommendations*, A-01-45 and A-01-46. <nasdac.faa.gov>.

8. FAA. *Brief Report for NTSB Safety Recommendations*, A-01-47 and A-01-48. <nasdac.faa.gov>.

9. Reed, Darcy; acting manager, FAA Aircraft Management Branch. Telephone interview by Lacagnina, Mark. Alexandria, Virginia, U.S., 31 January 2003. Flight Safety Foundation, Alexandria, Virginia. U.S.

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