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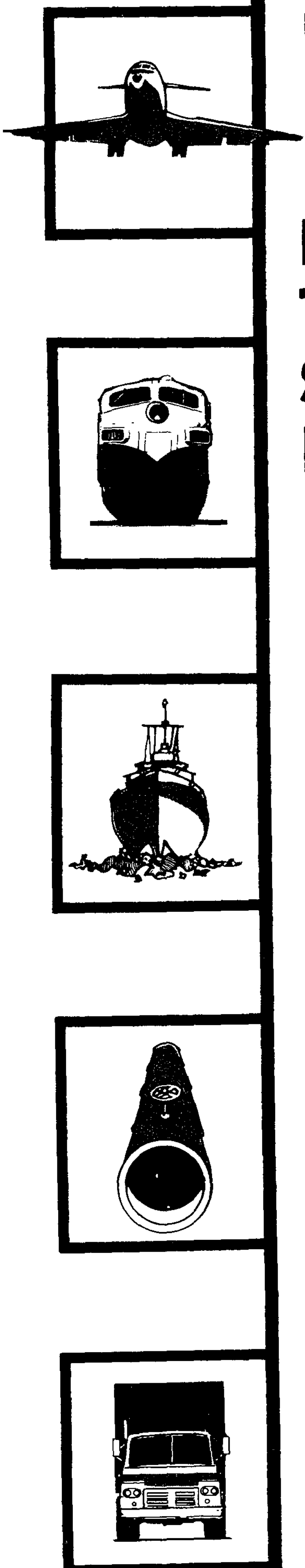

NATIONAL TRANSPORTATION SAFETY BOARD

WASHINGTON, D.C. 20594

AIRCRAFT ACCIDENT REPORT

McDONNELL DOUGLAS CORPORATION
DC-9-80, N980DC,
EDWARDS AIR FORCE BASE, CALIFORNIA
MAY 2, 1980

NTSB-AAR-82-2

UNITED STATES GOVERNMENT

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16. Abstract

About 0634 P.d.t, May 2, 1980, a McDonnell-Douglas, Inc., DC-9-80, N980DC, crashed while trying to land on runway 22 at Edwards Air Force Base, California.

The aircraft was on a certification test flight to determine the horizontal distance required to land and bring the aircraft to a full stop as required by 14 CFR 25.125 when the accident occurred.

The aircraft touched down about 2,298 feet beyond the runway threshold. The descent rate at touchdown exceeded the aircraft's structural limitations; the empennage separated from the aircraft and fell to the runway. The aircraft came to rest about 5,634 feet beyond the landing threshold of runway 22 and was damaged substantially. Seven crewmembers were on board; one crewmember, a flight test engineer, broke his left ankle when the aircraft touched down.

The National Transportation Safety Board determines that the probable cause of this accident was the pilot's failure to stabilize the approach as prescribed by the manufacturer's flight test procedures. Contributing to the cause of the accident was the lack of a requirement in the flight test procedures for other flight crewmembers to monitor and call out the critical flight parameters. Also contributing to this accident were the flight test procedures prescribed by the manufacturer for demonstrating the aircraft's landing performance which involved vertical descent rates approaching the design load limits of the aircraft.

17. Key Words Certification test flight, minimum horizontal landing distance, thrust management, rate of descent, stabilized approach.

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NATIONAL TRANSPORTATION SAFETY BOARD
WASHINGTON, D.C. 20594

AIRCRAFT ACCIDENT REPORT

Adopted: February 9, 1982

MCDONNELL-DOUGLAS CORPORATION, DC-9-80; N980DC EDWARDS AIR FORCE BASE, CALIFORNIA MAY 2, 1980

SYNOPSIS

About 0634 P.d.t, May 2, 1980, a McDonnell-Douglas, Inc., DC-9-80, N980DC, crashed while trying to land on runway 22 at Edwards Air Force Base, California.

The aircraft was on a certification test flight to determine the horizontal distance required to land and bring the aircraft to a full stop as required by 14 CFR 25.125 when the accident occurred.

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1. FACTUAL INFORMATION

1.1 History of the Flight

About 0634 P.d.t. 1/, May 2, 1980, a McDonnell-Douglas, Inc., DC-9-80, N980DC, crashed while trying to land on runway 22 at Edwards Air Force Base (AFB), California.

The aircraft had flown to Edwards AFB from Yuma, Arizona. After ground crew personnel and test equipment were unloaded, the aircraft took off to conduct a certification test flight. The flight was to be conducted to determine the aircraft's required landing distances pursuant to the provisions of 14 CFR 25.125.

1/ All times herein are Pacific daylight time based on the 24-hour clock.

The flightcrew consisted of the following personnel: a McDonnell-Douglas engineering test pilot who flew the aircraft and was in command of the flight; an FAA engineering test pilot who was in the right seat and performed the copilot's duties; a McDonnell-Douglas flight test engineer who was in the observer's seat to observe the flight test instrumentation and record critical data; a McDonnell-Douglas and an FAA flight test engineer who were standing behind the observer's seat to help gather test data; and two McDonnell-Douglas technicians who were seated at an instrument console in the cabin to monitor the test flight instrumentation.

The procedures used during this certification test landing were contained on a McDonnell-Douglas flight card and were, in part, as follows: based on a landing weight of about 132,500 pounds, the approach speed (Vref) was to be 1.3 Vs (30 percent above stall speed) and was to be held until 50 feet above the ground (AGL); 2/ at 50 feet, the target descent rate was to be 700 feet per minute (fpm) to 800 fpm and the thrust was to be reduced to idle; at 25 feet, the landing flare was to be started; and at 0.5 seconds to 0.75 seconds after main landing gear touchdown, full wheel brakes were to be applied. The target elapsed time to descend from 50 feet to main gear touchdown was to be 4.5 seconds to 5 seconds. The flap setting and computed Vref speed for this landing were 40 degrees and 133 knots indicated airspeed (KIAS), respectively.

About 452 feet, the pilot aligned the aircraft on the final approach course and began to stabilize the aircraft at the target descent rate and airspeed. Since the aircraft's head-up-display (HUD) portrayed airspeed, slow fast airspeed error, vertical speed, and radio altitude, the pilot said that he used the HUD exclusively during the approach. The pilot said that at 100 feet, the decision height to continue the approach, his maximum acceptable descent rate and airspeed were 720 fpm and Vref $\pm$ 2 KIAS, respectively. According to the pilot, at 100 feet his sink rate was between 710 fpm and 720 fpm and his airspeed was 132 KIAS; therefore, he decided to continue the approach and land.

Because the thrust had to be retarded to idle at 50 feet, the pilot said that after descending through 100 feet, he primarily concentrated on his radio altimeter readings. However, at about 55 feet, the pilot "perceived" a slight increase in the descent rate, and therefore he decided to delay the thrust reduction. He said that he thought he reduced the thrust to idle at about 37 feet and that he began his landing flare at about 20 feet. Based on his previous practice on this maneuver, the pilot said that the flare required definite "...back elevator...maybe half the available travel" of the control column. However, because he still "...had a perception of a slightly higher sink speed," he applied more back elevator force on the control column. The aircraft landed very hard, and as a result, the nose fell through and the nose wheel tires blew out. The pilot applied reverse thrust and wheel brakes, stopped the aircraft, and then shut the engines down and secured the aircraft. After he left the aircraft, the pilot saw that the empennage had separated and was lying on the runway.

The aircraft stopped about 5,634 feet beyond the landing threshold of the runway and about 28 feet left of the runway centerline. The accident occurred during daylight hours at coordinates 35° 54' 30" N latitude, and 117° 53' W longitude.

2/ All altitudes herein are height above the ground unless otherwise specified.

1.1.1 Flightcrew Observations

Because there was no HUD at the copilot's position, the copilot's recollection of performance data was based on his observations of the aircraft's instruments. He said that the pilot began to stabilize the aircraft on the approach below 500 feet. He thought the approach was "reasonably stable" to 100 feet, and at 100 feet, he said that he "....remembered seeing about 800 (fpm) minute rate of descent and about 135 KIAS. At that point I went outside (visually) and was not watching airspeed and descent rates." Thereafter, since there were no big changes of either aircraft attitude or thrust, the copilot believed that the approach remained as stable below 100 feet as it was above that height.

The copilot thought that the pilot reduced the thrust to idle at 50 feet, and that he "...pulled pretty hard...," on the control column when he rotated the aircraft. The copilot thought he saw "...a pretty pronounced rotation...," and he estimated that the aircraft's pitch attitude was about 6° to 8° nose up at main gear touchdown.

The flight test engineer in the observer's seat could not see the pilot's HUD. Because she "...was watching other things...," she could not provide specific airspeed and descent rate readings during the last 100 feet of the approach. Her duties required her to record certain specified data on the flight card for this maneuver. According to the annotations she made on the flight card, at 200 feet, the airspeed looked "normal;" at 100 feet, the airspeed was 134 KIAS; at 25 feet, the thrust was reduced to idle; the time to descend from 50 feet to main gear touchdown was 3.4 seconds; and the touchdown was "...very hard."

Two other flight test engineers were on board. One was required to record fuel readings and to time the descent from 50 feet AGL to touchdown. He was standing on the right side of the aircraft behind the flight test instrument console. During the approach, he moved to where he could see the radio altimeter, and at 50 feet he started his stop watch. He then returned to his position and looked out of one of the side windows. Based on his previous experience, the flight test engineer stated that he realized "...we were descending a bit faster than we had on the previous approaches..." and that the aircraft was going to land "...a lot harder than we had on the previous runs."

The other of these two flight test engineers was standing behind the observer's seat during the approach and was able to observe the aircraft's airspeed and vertical speed instruments. According to him, between 300 feet and 400 feet, the rate of descent was about 400 fpm and the airspeed was 135 KIAS. He said that at about 250 feet the pilot reduced thrust slightly "...presumably to decrease airspeed...and to increase (the) rate of descent toward the target..." descent rate. Thereafter, he stated that the pilot did not touch the thrust levers until just before landing, and during that time "...the airspeed was continually decreasing and the rate of sink increasing." The engineer remembered that at 100 feet, the airspeed was 132 KIAS; at 50 feet, it was about 130 KIAS and the rate of descent was about 800 fpm. The engineer stated that immediately after passing through 50 feet, the descent rate increased and the airspeed began to decrease rapidly. The last rate of descent he recalled seeing was about 1,000 fpm; he was not sure at what height he saw this, but it was immediately before touchdown.

The two technicians at the instrument console in the cabin were on board to insure that the flight test instrumentation systems were functioning properly during the flight. They said they had not observed any relevant performance data during the flight.

1.2 Injuries to Persons

Injuries	Crew	Passengers	Others
Fatal	0	0	0
Serious	1	0	0
Minor/None	6	0	0
Total	7	0	0

When the aircraft landed, one of the flight test engineers was standing behind the observer's seat, and his left foot was resting on the sloping surface (45°) of an instrument console channel flange on the floor of the aircraft. His left ankle was broken when the aircraft touched down.

1.3 Damage to the Aircraft

The aircraft was damaged substantially.

1.4 Other Damage

None.

1.5 Personnel Information

Both pilots were certificated in accordance with current regulations. (See appendix B.)

1.6 Aircraft Information

N980DC was the first DC-9-80 aircraft built. It was manufactured September 13, 1979, and was being operated by the McDonnell-Douglas Corporation under an experimental certificate. At the time of the accident, the aircraft had been flown 364.1 hours, and 64.1 hours since its last 100-hour inspection. The aircraft's maintenance history did not disclose any discrepancies or malfunctions which were relevant to the accident.

The aircraft was powered by two Pratt and Whitney JT8D-209 engines which have a normal takeoff static thrust rating of 18,500 pounds and a maximum takeoff thrust rating of 19,250 pounds. The total time on the engines was 364.1 hours.

The aircraft's maximum takeoff and landing gross weights were 142,000 pounds and 130,000 pounds, respectively. The forward and aft center of gravity (c.g.) limits were -0.8 percent M.A.C. and 33 percent M.A.C., respectively. At the time of the accident, the aircraft was about 2,500 pounds over its maximum allowable landing weight, and its c.g. was -0.8 percent M.A.C. The aircraft was operating under an experimental certificate for the purpose of showing compliance with airworthiness regulations, and the certification test being conducted involved a critical item affected by weight. Pursuant to 14 CFR 25.21(d), the allowable weight tolerance for this test was +5 percent, -1 percent.

1.7 Meteorological Information

The 0639 Edwards AFB surface weather observation was as follows: clear, visibility--45 miles; temperature--45 ° F; dew point--43° F; winds--calm; altimeter setting--30.08 inHg; fog bank north through southeast.

The pertinent winds aloft were as follows:

3,000 feet m.s.l. -- 240 at 4 knots
4,000 feet m.s.l. -- 280 at 4 knots
6,000 feet m.s.l. -- 020 at 8 knots

1.8 Aids to Navigation

Not relevant.

1.9 Communications

There were no reported communications difficulties.

1.10 Aerodrome Information

Edwards AFB, the United States Air Force (USAF) Flight Test Center, is located 60 nmi north of Los Angeles, California. Because of the facilities available at the base, commercial aircraft manufacturers use the base for testing pursuant to agreements made with the USAF. The landing runway, runway 22, is 15,000 feet long, 300 feet wide, and the elevation of the landing threshold is 2,288 feet m.s.l.

1.11 Flight Recorders

The aircraft was equipped with a Sunstrand Data Control Cockpit Voice Recorder (CVR), Serial No. 9126. The portion of the CVR tape which contained the final takeoff, traffic pattern, and landing were auditioned by Safety Board, FAA, and McDonnell-Douglas personnel at McDonnell-Douglas' Long Beach, California facility. During the flight, the flightcrew spoke only a few words and these pertained to required checklist actions. The tape revealed that no callouts of altitude, airspeed, or descent rates were made during the final approach; the tape corroborated the flightcrew's testimony that these callouts were not made. Since a transcript of the tape for this portion of the flight would have served no useful purpose, none was made.

The aircraft was equipped with an Inertial Navigation System (INS), test flight instrumentation, and a Sundstrand Digital Flight Data Recorder (DFDR), Serial No. 2862. The data from these systems were read out at the manufacturer's Long Beach, California facility in the presence of Safety Board personnel. The test flight instrumentation data were consistent with the DFDR data.

The DFDR and test flight instrumentation data revealed that the pilot made a descending left turn to the final approach course with the aircraft configured for landing. About 37 seconds before touchdown, at about 450 feet, the turn to the final approach course was completed; the airspeed was 131 KIAS and the rate of descent was about 910 fpm. The stabilizer trim setting was 11.17° aircraft noseup and it remained at, or within, 0.2° of that position throughout the final approach and landing.

During the descent from 450 feet to 225 feet, the pitch attitude of the aircraft increased from 4.1° noseup to about 6° noseup. At 450 feet, the engine pressure ratios (EPR) were 1.31 EPR on the left engine and 1.30 EPR on the right engine and at this point began to increase. At 275 feet, the left engine was at 1.45 EPR and the right engine was at 1.44 EPR. Thereafter, the thrust began to decrease, and at 228 feet, both engines were at 1.25 EPR. During this part of the approach, the descent rate decreased from 910 fpm to 400 fpm and the airspeed increased from 131 KIAS to the maximum value recorded—137 KIAS at 250 feet AGL. Thereafter, the airspeed began to decrease.

At 225 feet, engine thrust began another decrease, and at 150 feet AGL, the left and right engines were at 1.15 EPR and 1.14 EPR, respectively. These settings were maintained down to about 50 feet. Between 225 feet and 50 feet, the pitch attitude decreased from about 6° noseup and remained fairly constant between 5° noseup and 5.3° noseup. At 225 feet, the rate of descent began to increase. At 100 feet, the descent rate was about 840 fpm; at 50 feet, it was about 950 fpm. At 100 feet and 50 feet, the airspeed was 132 KIAS and 128 KIAS, respectively.

Shortly after descending through 50 feet, the engine pressure ratios began to decrease, and at 10 feet, both engines were at 1.1 EPR. When the aircraft touched down, the airspeed was 125 KIAS and the descent rate was 990 fpm (16.5 fps). About 2 seconds before touchdown, the trailing edges of the left and right elevators began deflecting upward, and at touchdown, they had been moved to 17° trailing edge up (TEU)--the maximum deflection available under these conditions. In response to this noseup input command, the aircraft began to rotate. Its pitch attitude increased from 5.01° noseup to 6.07° noseup and the pitch rate was increasing at touchdown.

Calculations based on the aircraft's landing weight and configuration indicated that at a constant 133 KIAS, a net thrust of 10,700 pounds would have been required to establish a constant descent rate of 720 fpm. Analysis of the flight data revealed that, between 450 feet and 260 feet, the net thrust (Net Thrust = Gross Thrust minus Ram Drag and Engine Bleed Loss) produced by the engines increased from 11,500 pounds to 16,600 pounds. Between 260 feet and 150 feet, the net thrust was reduced to about 5,800 pounds and remained at that value until it was reduced to idle after descending through about 42 feet. Calculations showed that 5,800 pounds net thrust would have increased the descent rate—at a constant 133 KIAS--to about 1,145 fpm.

The calculated descent rates cited above were based on both a constant thrust setting and airspeed. However, the dynamic relationship between acceleration and vertical speed is such that if the pilot maintained constant thrust and varied the pitch attitude to accelerate along the descending flight path, the rate of descent would increase; conversely, if the pilot decelerated the aircraft, the descent rate would decrease. However, the change in descent rate would only persist while the aircraft was accelerating or decelerating. Since the aircraft drag when in the landing configuration is at a minimum at or near Vref speed, the drag would begin to increase when the aircraft is decelerated below Vref. Consequently, if the deceleration is stopped and the aircraft is stabilized below Vref, the aircraft's rate of descent would increase rapidly unless an immediate addition to thrust is applied.

1.12 Wreckage and Impact Information

The aircraft's landing gear touched down about 2,298 feet beyond the landing threshold of runway 22; the aircraft then rolled an additional 3,336 feet along the runway and was brought to a stop about 28 feet to the left of the runway centerline. The nosewheels and nosewheel tires failed during the landing sequence and roll.

The empennage separated from the aircraft at fuselage station (FS) 1429, fell to the runway, and came to rest 18 feet right of the runway centerline and about 3,690 feet beyond the landing threshold of the runway. The vertical stabilizer and elevator were damaged when they struck the runway.

The top and side of the fuselage between FS 520 and FS 540 were buckled substantially, and various other locations on the fuselage sustained compression type buckling damage. Similar damage, but to a lesser degree, occurred at FS 1183 over the right cargo door and in the backup structure of the nose gear.

There was no visible damage to the main landing gear, wings, or interior of the aircraft. There were no fuel leaks.

1.13 Medical and Pathological Information

Not relevant.

1.14 Fire

There were about 32,400 pounds of jet-A fuel on board at landing. There was no fire.

1.15 Survival Aspects

The accident was survivable. After the aircraft stopped, the flightcrew opened the forward main entry door, extended the airstairs, and evacuated the aircraft.

1.16 Tests and Research

1.16.1 Landing Performance Tests

As a result of this accident, the Safety Board requested that McDonnell-Douglas assess the controllability and performance of the aircraft under the accident conditions either by simulation or by engineering analysis. Specifically, the Board asked that McDonnell-Douglas determine:

a. The minimum altitude at which the pilot could have introduced maximum longitudinal control input (up to but not beyond the angle of attack that would activate the stall warning stick shaker) with no increase in thrust which would reduce the descent rate at ground contact to the target value of less than 10 fps.

b. The minimum altitude at which the pilot could have made a longitudinal control input and thrust increase to cause the descent rate to decrease to zero and avoid ground contact.

McDonnell-Douglas performed these engineering analyses. The actual elevator and thrust lever (EPR settings) inputs during the accident sequence (starting at a radio altitude of 100 feet) were used. Existing aerodynamic data were modified to provide for ground effect.

The analysis of the first condition revealed that a flare initiated at 45 feet with full up-elevator input at a maximum rate could have reduced the descent rate to less than 10 fps (600 fpm) at touchdown. However, the data also indicated that the elevator input required complex management in order to avoid striking the tail on touchdown; with the main landing gear struts compressed, a tail strike will occur at a noseup pitch attitude of about 8.3°. The initial full up-elevator input (17.6° TEU) produced a 9° noseup pitch attitude; consequently, it could only be held for 0.75 seconds. Over the next 0.6 seconds, the elevator position was reduced to 5.4 TEU and this permitted the aircraft to rotate downward to an 8.03° noseup pitch attitude at touchdown. Although the target descent rate could have been attained, the analysis data indicated that the maneuver also exposed the aircraft to a potential tail strike at touchdown. Nevertheless, the data showed that the estimated pitch response and flare capability of the aircraft were adequate for the maneuver to have been performed.

The analysis of the go-around capability showed that if the go-around had been started at 50 feet it would have been completed successfully. During the engineering analysis, as the aircraft descended through 50 feet, the go-around was initiated with a 13.8° TEU elevator deflection followed 0.5 seconds later by the application of go-around thrust. With the elevators held at the position noted above, the aircraft rotated to a 11.8° noseup pitch attitude. The data showed that the aircraft would have descended 43 feet during the maneuver and cleared the runway by 7 feet.

During the DC-9-80 landing performance tests, a test pilot had made an actual go-around from 50 feet because of an excessive rate of descent (912 fpm) at that height. The aircraft was in the 40° flap landing configuration, its landing weight was 124,030 pounds, Vref was 128 KIAS, and the engine EPR's were 1.28 when the pilot began the go-around. At 50 feet, the pilot applied up-elevator and the elevators were deflected to 10 TEU. About 0.5 seconds after the elevator input, the thrust was increased to the go-around thrust, and the aircraft was rotated to a 8° noseup pitch attitude. Comparison of these data with the data derived in the go-around analysis above showed that the test aircraft's engines' thrust was slightly higher at the beginning of the maneuver. The elevator deflection on the test aircraft was the same as that used for the analysis; however, its noseup pitch attitude was 3.8° lower. During the actual go-around, the test aircraft descended 45 feet and it cleared the runway by about 5 feet. The data derived from the actual maneuver in conjunction with the data derived from the engineering analysis indicated that a successful go-around could have been made on the accident approach if the pilot had begun the maneuver at 50 feet.

1.16.2 Abused Landing Controllability Tests

At 25 feet and about 1 second before touchdown, the accident flight's test data showed that the pilot started a flare maneuver by deflecting the elevators to almost their full TEU position. The data revealed that this input occurred too late to reduce the descent rate although it did reduce the rate of increase in the descent rate. The landing performance demonstrations did not constitute a demonstration of elevator effectiveness under conditions of minimum speeds. Therefore, after the accident, the FAA, pursuant to the conditions contained in 14 CFR 25.143(a)(5), required McDonnell-Douglas to conduct abused landing maneuvers to demonstrate adequate elevator effectiveness. 14 CFR 25.143 (a)(5) requires the manufacturer to demonstrate, in part, that "The airplane must be safely controllable and maneuverable during...landing."

The abused landing demonstrations were to show that the DC-9-80 did not have unsafe control characteristics on the landing approach at speeds below 1.3 Vs. In order to satisfy this requirement, the same procedures used in the landing distance tests were used for this demonstration with the following exceptions: at 50 feet, the target speed was 1.3 Vs minus 5 KIAS; the pilot could start the landing flare maneuver at any height below 50 feet; and the pilot could reduce the thrust at any altitude below 50 feet that would produce a touchdown speed that was 5 KIAS below the landing speeds used for the landing distance tests.

Two abused landing demonstrations were flown. The aircraft's landing gross weights were about 13,000 pounds below that of the accident aircraft. The test data recorded on the two demonstrations showed that the target speeds were met at 50 feet; the descent rates at 50 feet were 768 fpm and 648 fpm, respectively; the flare maneuvers were started at 23 feet and 31.8 feet, respectively, with up-elevator inputs of about 10 TEU and 12 TEU, respectively; engine thrust was reduced to idle at 9.9 feet and 1.4 feet, respectively; and the descent rates at touchdown were 240 fpm and 300 fpm, respectively. The tests met the FAA certification requirements for demonstrating acceptable flight characteristics during a landing flare maneuver.

Following the completion of the abused landing controllability tests, the landing performance demonstrations were conducted. Twelve landings were made at gross weights between 129,000 pounds and 109,200 pounds at the forward c.g. limit of -0.8 percent M.A.C. Six landings were made with a 40° flap setting and six landings were made with the flaps set at 28°. The aircraft's anti-skid system was on, the auto-spoiler system was armed, the hydraulic and pneumatic systems were normal, and the landings were made on a dry runway. The tests were accepted by the FAA and the resultant data were used to determine the landing distances for the Airplane Flight Manual.

1.17 Other Information

1.17.1 Regulations and FAA Orders

14 CFR 25.125 (see appendix C) requires the applicant for an airworthiness certificate to determine the horizontal distance necessary to land the aircraft and bring it to a complete stop from a point 50 feet above the landing surface. The regulation establishes the weights and altitudes at which this distance must be determined and how the certification demonstration must be conducted. According to the regulation, the applicant must place the aircraft in its landing configuration and establish and maintain a "steady gliding approach with a calibrated airspeed of not less than 1.3 Vs..." down to 50 feet. Changes in configuration, thrust, and speed must be made in accordance with procedures established for service operation. The regulation prohibits the use of reverse thrust during the landing and roll and also states that, "The landings may not require exceptional piloting skills or alertness."

The maximum rate of descent at touchdown for the design landing weight was established by the structural requirements in 14 CFR 25.473 (ii), as 10 fps (600 fpm).

FAA Order 8110.8. Engineering Flight Test Guide for Transport Category Aircraft, paragraph 59 (b)(3) repeats the requirement to establish a steady 1.3 Vs airspeed, and then states, "The landing speed should be compatible with landings under expected service conditions within the level of skill anticipated from the crew in service. Once these conditions have been established, there should be no appreciable change in the power, attitude, or rate of descent prior to reaching a height of 50 feet above the landing surface. No changes in configuration, addition of thrust, or nose depression should be made after reaching the 50 feet height."

14 CFR 121.195 (see appendix C) establishes the operational limitations for landing and are based on the landing distances determined during the certification test flights. This regulation states, in part, that no person may land a turbine engine powered transport category aircraft unless landing weight would allow a full stop landing within 60 percent of the effective length of the runway "...from a point 50 feet above the intersection of the obstruction clearance plane and the runway." 14 CFR 121.197 similarly concerns alternate airports, and the landing distance requirements cited therein are identical to those contained in 14 CFR 121.195. Thus, an air carrier must, in conducting its airport analyses, compute allowable landing weights which will permit the aircraft to be stopped within 60 percent of the effective length of the runway selected for landing.

1.17.2 Head Up Display (HUD)

The accident aircraft was equipped with a Sundstrand, Inc., DLU 601, HUD. The HUD provided guidance information, centered about the predicted touchdown point,

focused at infinity, and displayed on a combiner coincident with the pilot's forward field of view. The combiner optics, whether in use or in the stowed position, are designed so as not to obstruct either pilot's field of view. The system is designed to provide essential information to the pilot during ILS and non-ILS approaches.

During this non-ILS approach, the following pertinent data were displayed on the combiner optics for the pilot's use: an aircraft guidance symbol (above 100 feet the symbol is a straight line, and at 100 feet, the straight line is changed to a miniature aircraft symbol); a digital readout of indicated airspeed and radio altitude; a digital readout of descent rate in 10 fpm increments available down to 45 feet, thereafter it is deleted from the presentation; and a slow/fast airspeed error indicator (speed worm). The slow/fast airspeed error is referenced to the speed selected by the pilot and set in the speed command window of the autothrottle system. The airspeed error is depicted by a barber pole symbol which either rises (fast) or descends (slow) from the airplane symbol.

The instrument data displayed by the HUD are inserted in the HUD computers from the aircraft's flight guidance and central air data computers (CADC). Data portrayed by the HUD during the accident flight was compared with data from other flight test instruments. Except for the fact that the radio altimeter read 7 feet higher than the tapeline altitude (this was determined during the build-ups before the accident, therefore, the thrust was to be reduced to idle when the radio altimeter read 57 feet instead of 50 feet), the comparison indicated that the HUD system functioned normally.

1.17.3 Flightcrew Procedures

During the 3 weeks before the accident, 25 to 30 practice approaches and landings--build-ups--were flown by the test pilot. In addition to providing the test pilots practice in performing the maneuver, the build-ups were performed to determine the highest height at which the thrust could be retarded to idle and the lowest height at which the flare could be started and still achieve touchdown at a sink rate between 600 fpm (10 fps) and 480 fpm (8 fps). The overall purpose of the build-ups was to develop procedures and pilot techniques which would produce a touchdown within the target sink rates with the engines spooled down to idle thrust and to provide the minimum air distance from 50 feet to touchdown. During these build-ups, the flight card procedures used for the certification test flight were developed.

According to the pilot, the descent rate was controlled by thrust, and if the airspeed was stabilized, he would use thrust to vary the descent rate. The entire approach and landing, once stabilized, was flown at the same pitch attitude which remained the same throughout the landing flare.

The purpose of the flare maneuver was to counteract the pitch down moment encountered as the aircraft entered ground effect. Essentially, an aircraft begins to encounter the aerodynamic influences of ground effect when it descends below a height equal to its wingspan--the DC-9-80's wingspan is 107.8 feet. According to the pilot, the flare maneuver, if accomplished properly, merely counteracted the nose-down pitch and kept the aircraft at the same pitch attitude. Based on the previous build-ups, that attitude was generally about 5° noseup.

The pilot said that if at 100 feet the aircraft was stabilized at the desired speed and descent rate, it would touchdown within the desired parameters provided the thrust and pitch attitude were maintained down to 50 feet. All that had to be done thereafter was to reduce the thrust and begin the flare at the proper heights. Therefore,

after 100 feet, he primarily concentrated on the radio altimeter to insure that the thrust was reduced and that the flare was started at the correct altitudes. In addition, the pilot said that because of a change in position error caused by ground effect in the airspeed and vertical velocity indicators, their readings were apt to be unreliable as the aircraft descended below 100 feet.

The procedure developed during these build-ups did not require the non-flying pilot to call out altitudes, airspeeds, or any deviation of these two parameters from the desired values. However, the pilot stated that he had briefed the crewmembers that "anytime anybody sees something they don't like, they are to speak up, and if I don't agree with them, then I said we'll stop with whatever we're doing and we'll talk about it on the ground. I will not continue a test if everybody on board is not satisfied with what we are doing."

Finally, the entire build-up series was flown with the same FAA test pilot serving as one of the flightcrew. After the series had been completed, this pilot was assigned a new task. The replacement FAA pilot on the accident flight had flown this maneuver in other type aircraft, but he had never flown it in a DC-9 type aircraft. He said that he was trying to learn how it was done so he could perform some of the later certification landings. He was not familiar with what he was seeing, and he said that had he been more familiar, he "...might have been of more help..." to the pilot.

2. ANALYSIS

The aircraft was maintained in accordance with prescribed regulations and procedures. Both pilots were qualified in accordance with prescribed regulations.

Since the tests conducted after the accident demonstrated that the aircraft's control capability throughout the landing regime of flight was satisfactory, the main thrust of the inquiry was directed to the procedures and pilot techniques used during the landing demonstrations and the certification regulations under which they were performed.

The practice build-up maneuvers conducted before the certification test flight served two purposes. In addition to establishing the procedures which would provide the shortest landing distance, they provided training for the flightcrew. Essentially, the pilot was trained to establish and to stabilize his aircraft at Vref and at a 700 to 800 fpm descent rate. Once the aircraft was stabilized at this speed and descent rate, the pilot could establish a sight picture of his projected touchdown point on the runway, and coupled with this visual picture and the instrument readings, the pilot could maintain the required "steady gliding approach" to 50 feet. Once stabilized, speed could be controlled with small pitch variations and sink rate could be controlled with small thrust corrections.

Because of the change in the position errors of the airspeed and vertical velocity indicators as the aircraft descended into ground effect, the pilot said these instruments could not be relied upon for precise guidance during the last 50 feet of the approach. Therefore, it was imperative that the aircraft be stablized at the target descent rate and airspeed before reaching 100 feet -- the decision altitude. Assuming that the aircraft descended through 100 feet with its descent rate, airspeed, and thrust stabilized, there was no need for the pilot to direct a high level of concentration to his airspeed and vertical velocity indicators as the aircraft entered ground effect. Since the thrust levers were to be retarded at 50 feet, with a 700 fpm descent rate, the aircraft would reach that height within 3.6 to 3.7 seconds after leaving 100 feet. Therefore, little, if any, perturbations from the target airspeed and descent rate could occur if a constant

pitch attitude were maintained during this interval. Finally, as shown during the build-ups, if the thrust reduction and flare were performed at the target altitudes, touchdown would occur within the desired parameters. Consequently, the success of the maneuver was predicated on the following: before reaching 100 feet, the thrust had to be stabilized at or near the values which would produce and maintain the target descent rate and airspeed, and these parameters had to remain stabilized as the aircraft descended through 100 feet.

The performance data recorded on the accident flight showed that the pilot established his aircraft on the landing runway heading as it was descending through 452 feet, and the aircraft touched down 37 seconds later. Since the aircraft's thrust, airspeed, and descent rate had to be established before reaching 100 feet, assuming that he was able to establish a 700-fpm descent rate, the pilot had less than 30 seconds to stabilize his aircraft at the desired paramenters. The data showed that he did not do this.

During the descent, one of the most important, if not the most important, tasks for the test pilot was to establish the thrust setting that would provide a constant 700 fpm to 800 fpm rate of descent at 133 KIAS. Performance calculations showed that about 10,700 pounds net thrust would produce this rate. At 452 feet, when the pilot finally aligned the aircraft with the landing runway, the aircraft's rate of descent was 920 fpm, its airspeed was 131 KIAS, and its net thrust was 11,500 pounds. Thereafter, the pilot began to increase thrust, and at 260 feet, the net thrust had been increased to 16,600 pounds. Had the pilot stabilized his aircraft at and maintained Vref, this thrust level would have resulted in a descent rate of 100 fpm. However, since at 452 feet, the airspeed was below Vref, the pilot also permitted the aircraft to accelerate along the flight path. This acceleration resulted in the rate of descent decreasing more slowly. As a result of this acceleration and the thrust increase, when the aircraft reached 250 feet, the airspeed had increased to Vref plus 4 KIAS and the descent rate had decreased to 400 fpm. Another thrust correction was required if the targeted values of descent and airspeed were to be met at 100 feet.

At 260 feet, the pilot reduced the net thrust to about 6,000 pounds, and began to increase the descent rate and, at the same time, decrease the indicated airspeed. At a constant Vref, this thrust setting would have produced about a 1,250-fpm descent rate. However, since the aircraft was decelerating, the descent rate increased at a slower rate. At about 160 feet, Vref was reached; however, the pilot continued to allow the aircraft to decelerate below this speed. Between 160 feet and 110 feet, although the descent rate continued to increase, the rate of increase was slower than before. In addition, the rate at which the airspeed was decreasing had also slowed.

At 100 feet, the decision altitude, the transient descent rate was 800 fpm and the transient airspeed was 131 KIAS. These data showed that the indicated airspeed and descent rate were within 1 KIAS and 80 fpm, respectively, of what the pilot said his instruments were reading at that altitude. However, both parameters were changing as the approach was not stabilized. At 100 feet, the net thrust was about 5,000 pounds below the thrust needed to maintain a stabilized 720 fpm descent at Vref; the airspeed was 2 KIAS below Vref and decreasing while the descent rate exceeded 720 fpm and was increasing. In addition, since the airspeed was now below Vref and decreasing, the aircraft's drag was increasing. The effects of the thrust deficiency and increasing drag were now predominant, and, unless the thrust was increased, the aircraft would continue to decelerate and the rate of descent would keep increasing.

At 40 feet, despite the decreasing airspeed and increasing descent rate, the pilot reduced the thrust to idle. At 25 feet, about 2 seconds before touchdown, the pilot

began the flare maneuver and within 1.5 seconds he had applied almost full up-elevator. At this time, the airspeed was 126 KIAS and the descent rate was 990 fpm. During the last 20 feet of the descent, the elevator input produced a noseup rotation, and at touchdown, the aircraft's pitch attitude had increased about 1° to a 6° noseup pitch altitude. This rotation stopped the aircraft's vertical acceleration, but it did not produce a decrease in the rate of descent.

Based on INS vertical speed data, at main gear touchdown, the sink rate was about 16.2 fps. The main gear became airborne about 0.5 seconds after touchdown; 0.2 seconds later the nose gear touched down, and 0.4 seconds after the nose gear touched down the main gear touched down again. The sink rate at touchdown exceeded the aircraft's ultimate vertical speed limitation for landing (12.25 fps) and initiated failures at the fuselage locations described in this report.

In summary, the evidence indicated that the pilot did not allow sufficient time, distance, and altitude on the final approach to stabilize his aircraft before reaching the decision height. Correlation of the pilot's statement with performance data indicated that, based on the temporary decrease in the rates of change in both descent rate and airspeed as the aircraft approached the decision altitude, the pilot believed that the approach was stabilizing and decided to land. Although the aircraft reached 100 feet with its indicated airspeed and descent rate within the parameters established to continue the approach, the aircraft was not stabilized on the descent. In particular, the net thrust was 5,000 pounds below the thrust required to maintain the desired descent rate and airspeed. The pilot did not recognize that the approach was not stabilized. Although he sensed the increasing sink rate, he did not perceive its magnitude and he did not try to verify its magnitude by cross checking his vertical velocity indicator readout. The Safety Board believes that the pilot's failure to recognize that his aircraft was not stabilized on the descent at or before reaching 100 feet was the precipitating factor of this accident.

The Safety Board also noted that, despite the criticality of airspeed and descent rate during the maneuver, the manufacturer's procedures developed for this test did not assign any crewmember the responsibility of monitoring these parameters as a backup to the pilot. Almost every air carrier procedure assigns the task of calling out variations in airspeed and sink rate to the non-flying pilot during the landing; however, these procedures were not required of the non-flying pilot during these tests. Since the investigation showed that a missed approach capability existed down to 50 feet, the Safety Board believes that if the procedure had required this back-up function and if it had been performed properly the accident might have been avoided.

After checking to see that the aircraft and descent rate were within the prescribed limits at the decision altitude, the copilot transferred his attention outside the aircraft to familiarize himself with the visual picture of the final phases of the approach and landing. The procedures did not prescribe any precise monitoring duties for him.

The pilot said he had instructed the crewmembers to "...speak up..." if they saw anything they did not like and he would then discontinue the test flight. With regard to the flight test engineers, it would appear that they interpreted the instructions to mean instrument malfunctions or reading errors that would invalidate the test results. Nevertheless, had any of the test flight engineers noticed and called the increasing descent rate to the pilot, his subsequent conduct of the flight might have changed.

As previously stated, these landing distance tests are required by the aircraft certification regulations. The provisions of 14 CFR 25.125 and the applicable sections of FAA Order 8110.8 cited herein established the aircraft's landing configuration; how the

approach was to be flown down to 50 feet; and the limitations applicable to changes of thrust, speed, and aircraft configuration. With regard to the descent from 50 feet to touchdown, FAA Order 8110.8 states, "No changes in configuration, addition of thrust, or nose depression should be made after reaching the 50 feet height." Except for the requirement that "....the landing must be made without excessive vertical acceleration...," no further specific limitation concerning procedures or performance are imposed upon the applicant for certification. With regard to what constituted "excessive vertical acceleration," the maximum rate of descent for the design landing weight is 10 fps; therefore, McDonnell-Douglas established 10 fps as the maximum allowable sink rate at which the landing data were acceptable. Thus, within these performance and procedural constraints, McDonnell-Douglas developed and established procedures and pilot techniques which would provide the shortest landing distance.

In addition to the performance and procedural constraints discussed above, 14 CFR 25.125(a)(5) states "The landings may not require exceptional piloting skill or alertness." The question then is whether the procedures used during these tests exceeded the subjective limitation imposed by this paragraph. The procedures used for the test can be divided into two phases: the approach to 50 feet, and the approach from 50 feet to landing. Since the approach procedure of almost every air carrier states that the only permissible additive to Vref speed that may be carried over the landing threshold of the runway is the wind gust correction factor, the test procedures used during the descent to 50 feet were essentialy the same as those used during the line operations of most air carriers.

On the other hand, the techniques used after leaving 50 feet require precise action by the pilot; thus, this portion of the maneuver required practice and repetition in order for the test pilots to acquire the needed proficiency and skill to perform the maneuver correctly. However, line pilots are not required nor encouraged to land their aircraft in a manner in which limit structural loads can be imposed on the aircraft because minimum landing distances, as established during the test landings, are not used for line operations, but rather as the baseline for determination of operational runway requirements. The required operational runway length for landing at any given landing weight is derived by multiplying the certification landing distances obtained using these test techniques by 1.667; or stated another way, the aircraft can be stopped within 60 percent of the effective length of the required landing runway length. Thus, a line pilot has a safety margin and is not required to replicate the stopping distances derived from these certification tests.

Although the procedures used for the certification test are not representative of the manner in which the aircraft is landed during routine line operations, the Safety Board is also aware that similar, if not identical, pilot procedures have been used to demonstrate the landing distances of almost all turbine jet engine powered aircraft certificated in the United States. The fact that these procedures have been used successfully during the certification of these aircraft indicated that, with practice, the test pilots have and can perform this maneuver successfully. Despite this, the Board remains concerned about the risks associated with the test maneuver. In order to produce the minimum air distance from 50 feet, the test pilot must land his aircraft at sink rates which are close to the aircraft's limit loads and which can, if the pilot is imprecise, approach the aircraft's ultimate load limits; certainly a procedure which cannot be endorsed for any line operation. Under these circumstances, it would appear logical, and certainly safer, that these landing distances be determined in a different manner. The Safety Board believes that the landing distance determination should be conducted using procedures which are more representative of the way the aircraft is landed during line

operations. If the use of such procedures unnecessarily restricts the operational limitations of an aircraft beyond the present limitations required by 14 CFR 121.195, the Safety Board believes that both the certification demonstration techniques and the operational landing distance requirements should be reviewed to ensure that they provide safety during both certification and operation of the aircraft.

3. CONCLUSIONS

3.1 Findings

1. The accident occurred during a certification test flight.

2. The purpose of the certification test flight was to demonstrate the horizontal distance required to land and bring the aircraft to a full stop as prescribed by 14 CFR 25.125.

3. The pilot techniques developed during the build-up flights were designed to provide the minimum landing distances.

4. The pilot used the aircraft's HUD exclusively to monitor critical performance parameters during the approach and landing. The HUD system functioned normally during the accident.

5. The decision height for continuing the approach to a landing was 100 feet.

6. The success of the maneuver was predicated on the the airspeed, descent rate, and engine thrust being stabilized before reaching 100 feet and then maintaining these stabilized values through 100 feet until the thrust was retarded to idle at 50 feet.

7. At 100 feet, the airspeed and rate of descent were reading at or very near the values established for continuing the landing approach; therefore, the pilot did not perceive the need to start a go around.

8. The pilot did not stabilize the aircraft at the targeted airspeed, descent rate, and engine thrust before reaching 100 feet. At 100 feet, the descent rate was increasing, the airspeed was decreasing and the thrust level was too low to sustain the aircraft at or below the maximum allowable sink rates.

9. The pilot failed to perceive the magnitude of the sink rate and therefore did not execute either a go-around or apply additional thrust during the flare to arrest and decrease the descent rate.

10 The aircraft touched down at a sink rate which exceeded its structural limits and as a result was substantially damaged.

11. The procedures and techniques used for the maneuver required a high degree of skill and alertness on the part of the test pilot.

12. The minimum landing distances derived during the landing distance certification tests are multiplied by 1.667 to establish the operational

runway lengths required by the FAR for normal line operational landings; therefore, line pilots do not have occasion to use the procedures used during the landing distance certification test flight.

3.2 Probable Cause

The National Transportation Safety Board determines that the probable cause of this accident was the pilot's failure to stabilize the approach as prescribed by the manufacturer's flight test procedures. Contributing to the cause of the accident was the lack of a requirement in the flight test procedures for other flight crewmembers to monitor and call out the critical flight parameters. Also contributing to this accident were the flight test procedures prescribed by the manufacturer for demonstrating the aircraft's landing performance which involved vertical descent rates approaching the design load limits of the aircraft.

4. RECOMMENDATIONS

As a result of its investigation of this accident, the National Transportation Safety Board recommended that the Federal Aviation Administration:

> Revise the procedures which are currently being used to demonstrate minimum landing distances for compliance with 14 CFR 25.125 for certification of transport category airplanes to: (a) provide a higher margin of safety during certification and (b) establish landing distances which are more representative of those encountered when an airplane is operated during air carrier service. (Class II, Priority Action) (A-82-24)
>
> Upon adoption of revised procedures for demonstrating operational landing distances for compliance with 14 CFR 25.125, review the operational runway length limitations in 14 CFR 121.195 which are applied to certification landing distances so that they do not unjustifiably penalize the operational specifications of airplanes. (Class II, Priority Action) (A-82-25)

BY THE NATIONAL TRANSPORTATION SAFETY BOARD

/s/ JAMES E. BURNETT, JR.
Acting Chairman

/s/ FRANCIS H. McADAMS
Member

/s/ PATRICIA A. GOLDMAN
Member

/s/ G. H. PATRICK BURSLEY
Member

February 9, 1982

5. APPENDIXES

APPENDIX A

INVESTIGATION AND HEARING

1. Investigation

The Los Angeles Office of the National Transportation Safety Board was notified of the accident at 0730, on May 7, 1980. Two investigators were immediately dispatched to the scene, and were later joined by a performance specialist from the Board's Bureau of Technology in Washington, D.C.

Parties to the investigation were the FAA and the McDonnell-Douglas Corporation. USAF Safety Officers provided assistance during the documenting of the aircraft wreckage.

2. Public Hearing and Depositions

There was no public hearing and depositions were not taken.

APPENDIX B

PERSONNEL INFORMATION

Pilot

Pilot John P. Lane, 57, was employed by the McDonnell-Douglas Corporation as an engineering flight test pilot. He held Airline Transport Pilot Certificate No. 1433558 with airplane multiengine land, single engine land, and helicopter ratings. He was type rated in the McDonnell-Douglas DC-9 aircraft. Mr. Lane's first class medical certificate was issued October 8, 1979, and he was required to wear corrective lenses while exercising his airman's privileges. His medical certification had been issued more than 6 months before the flight; therefore, he was exercising the commercial privileges of his Airline Transport Pilot Certificate. According to the pilot, he was wearing his glasses during the flight.

Mr. Lane had flown about 6,000 hours. He had flown 700 hours in DC-9 aircraft, 265 of which were in the DC-9-80. He had been off duty more than 12 hours before reporting for this flight.

Copilot

Copilot Donald A. Alexander, 46, was employed by the FAA as a flight test pilot. He held Airline Transport Pilot Certificate No. 1310586 with airplane multiengine land, single engine land, and single engine sea ratings. He was type rated in Boeing 377, 727, Lockheed 300, and McDonnell-Douglas DC-9 aircraft. Mr. Alexander's first class medical certificate was issued April 29, 1980, with no limitations.

Mr. Alexander had flown 6,500 hours. He had flown 40 hours in DC-9 aircraft, 25 of which were in the DC-9-80. Mr. Alexander had been off duty for more than 12 hours before reporting for this flight.

APPENDIX C

PERTINENT FEDERAL AVIATION REGULATIONS

14 CFR 25.125 Landing

(a) The horizontal distance necessary to land and to come to a complete stop (or to a speed of approximately 3 knots for water landings) from a point 50 feet above the landing surface must be determined (for standard temperatures, at each weight, altitude, and wind within the operational limits established by the applicant for the airplane) as follows:

(1) The airplane must be in the landing configuration.

(2) A steady gliding approach, with a calibrated airspeed of not less than 1.3 Vs must be maintained down to the 50-foot height.

(3) Changes in configuration, power or thrust, and speed, must be made in accordance with the established procedures for service operation.

(4) The landing must be made without excessive vertical acceleration, tendency to bounce, nose over, ground loop, porpoise, or water loop.

(5) The landings may not require exceptional piloting skill or alertness.

(b) For landplanes and amphibians, the landing distance on land must be determined on a level, smooth, dry, hard-surfaced runway. In addition--

(1) The pressure on the wheel braking systems may not exceed those specified by the brake manufacturer.

(2) The brakes may not be used so as to cause excessive wear of brakes or tires; and

(3) Means other than wheel brakes may be used if that means--

(i) Is safe and reliable;

(ii) Is used so that consistent results can be expected in service; and

(iii) Is such that exceptional skill is not required to control the airplane.

(c) For seaplanes and amphibians, the landing distance on water must be determined on smooth water.

(d) For skiplanes, the landing distance on snow must be determined on smooth, dry, snow.

(e) The landing distance data must include correction factors for not more than 50 percent of the nominal wind components along the landing path opposite to the direction of landing, and not less than 150 percent of the nominal wind components along the landing path in the direction of landing.

(f) If any device is used that depends on the operation of any engine, and if the landing distance would be noticeably increased when a landing is made with that engine inoperative, the landing distance must be determined with that engine inoperative unless the use of compensating means will result in a landing distance not more than that with each engine operating.

14 CFR 121.195 Transport category airplanes: Turbine engine powered: Landing limitations: Destination airports.

(a) No person operating a turbine engine powered transport category airplane may take off that airplane at such a weight that (allowing for normal consumption of fuel and oil in flight to the destination for alternate airport) the weight of the airplane on arrival would exceed the landing weight set forth in the Airplane Flight Manual for the elevation of the destination or alternate airport and the ambient temperature anticipated at the time of landing.

(b) Except as provided in paragraphs (c), (d), or (e) of this section, no person operating a turbine engine powered transport category airplane may take off that airplane unless its weight on arrival, allowing for normal consumption of fuel and oil in flight (in accordance with the landing distance set forth in the Airplane Flight Manual for the elevation of the destination airport and the wind conditions anticipated there at the time of landing), would allow a full stop landing at the intended destination airport within 60 percent of the effective length of each runway described below from a point 50 feet above the intersection of the obstruction clearance plane and the runway. For the pupose of determining the allowable landing weight at the destination airport the following is assumed:

(1) The airplane is landed on the most favorable runway and in the most favorable direction, in still air.

(2) The airplane is landed on the most suitable runway considering the probable wind velocity and direction and the ground handling characteristics of the airplane, and considering other conditions such as landing aids and terrain.

(c) A turbopropeller powered airplane that would be prohibited from being taken off because it could not meet the requirements of paragraph (b)(2) of this section, may be taken off if an alternate airport is specified that meets all requirements of this section except that the airplane can accomplish a full stop landing within 70 percent of the effective length of the runway.

(d) Unless, based on a showing of actual operating landing techniques on wet runways, a shorter landing distance (but never less than that required by paragraph (b) of this section) has been approved for a specific type and model airplane and included in the Airplane Flight Manual, no person may take off a turbojet powered airplane when the appropriate weather reports and forecasts, or a combination thereof, indicate that the runways at the destination airport may be wet or slippery at the estimated time of arrival unless the effective runway length at the destination airport is at least 115 percent of the runway length required under paragraph (b) of this section.

(e) A turbojet powered airplane that would be prohibited from being taken off because it could not meet the requirements of paragraph (b)(2) of this section may be taken off if an alternate airport is specified that meets all the requirements of paragraph (b) of this section.

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