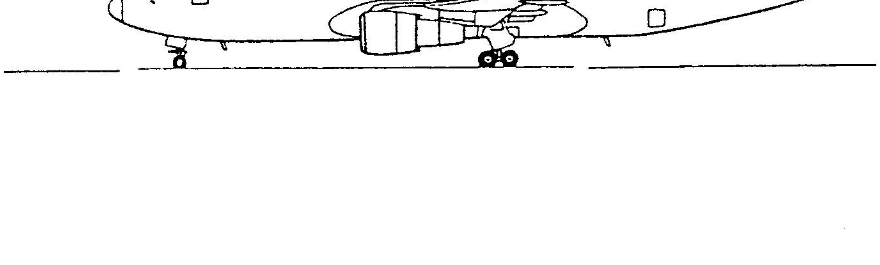
# 5

# Flight test determination of takeoff performance



# OBJECTIVES

1. Determine takeoff speed schedule for all conditions within airplane operational limits.

2. Determine takeoff distance and climb performance using appropriate speed schedule.

# FAR 23 - TAKEOFF SPEEDS

$V_{SO}$ Stall speed in the landing configuration
$V_{S1}$ Stall speed in a specific configuration

**For normal, utility, and acrobatic airplanes**

$V_R$ Rotation speed,
- $\geq V_{S1}$ (single engine)
- $\geq 1.05\ V_{MC}$, $\geq 1.1\ V_{S_1}$ (multi-engine)

$V_{50}$ Speed at 50 ft AGL,
- $\geq 1.2\ V_{S1}$ (single engine)
- $\geq 1.1\ V_{MC}$, $\geq 1.2\ V_{S_1}$ (multi-engine)

**For commuter category airplanes**

$V_1$ Takeoff decision speed $> V_{EF}$
$V_{EF}$ Airspeed at which critical engine fails,
- $\geq 1.05\ V_{MC}$ or
- $\geq V_{MCG}$

$V_R$ Rotation speed,
- $\geq V_1$
- $\geq 1.05\ V_{MC}$
- $\geq 1.1\ V_{S1}$

Must result in $V_2$ before 35 ft AGL

$V_2$ Airspeed at or before 35 ft AGL
- $\geq 1.1\ V_{MC}$
- $\geq 1.2\ V_{S1}$

# FAR 25 - TAKEOFF SPEEDS

$V_S$ Stall speed

$V_{EF}$ Airspeed at which critical engine fails, $\geq V_{MCG}$

$V_1$ Takeoff decision speed, $>V_{EF}$

$V_2$ Airspeed attained at or before 35 ft height after engine failure at $V_{EF}$

$V_{2_{MIN}}$ $\geq 1.1V_{MC}$
$\geq 1.2V_S$

$V_{mu}$ Minimum unstick speed, AEO and OEI

$V_R$ Rotation speed, $\geq V_1$
$\geq 1.05\ V_{MC}$

Must result in $V_2$ before 35 ft height
Must result in

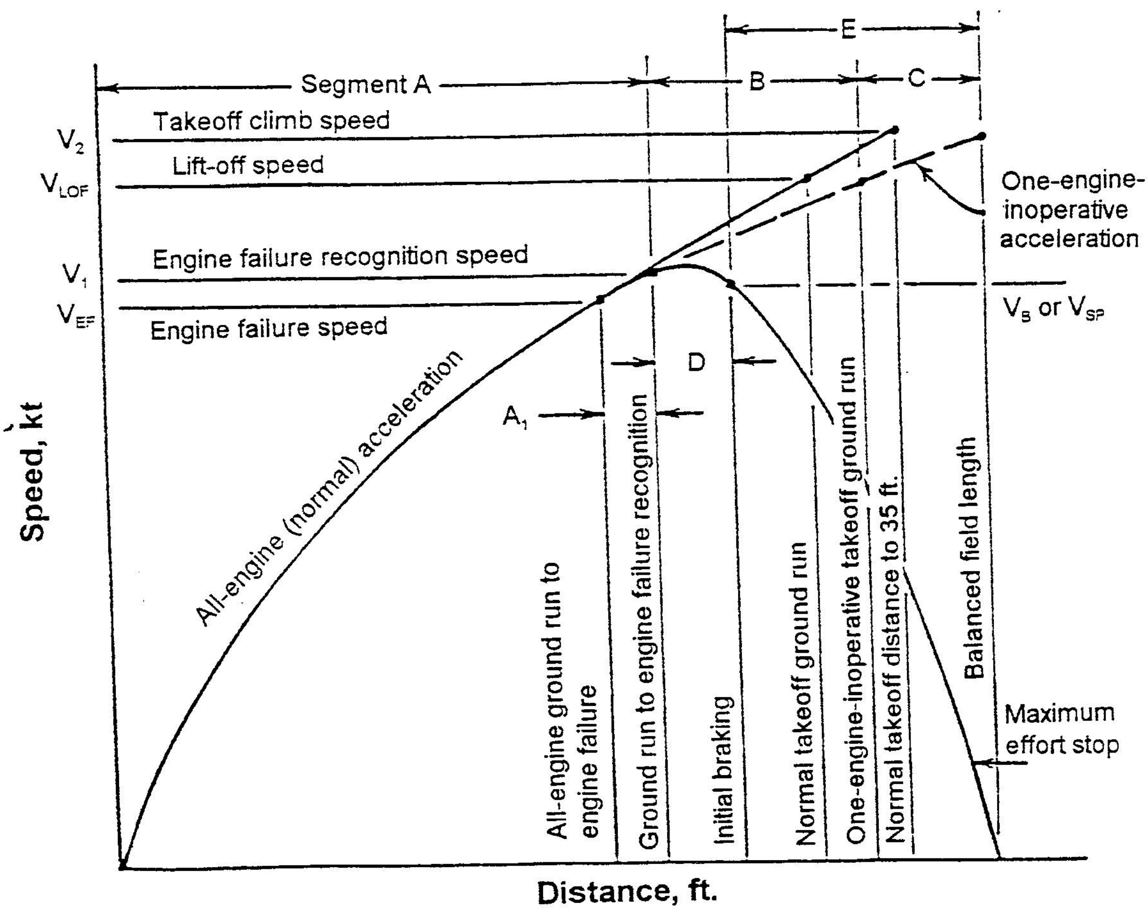
$V_{LOF}$ $\geq 1.1V_{mu}$ (all engines)
$\geq 1.05V_{mu}$ (one engine out)
$\geq 1.08V_{mu}$ (AEO, geometry limited)

$V_{LOF}$ Airspeed at which airplane first becomes airborne

$V_{MC}$ Engine inoperative minimum control speed in flight, $\leq 1.2\ V_S$

$V_{MCG}$ Minimum control speed on ground with OEI

# Balanced Field Length



# GROUND MINIMUM CONTROL SPEED $V_{MCG}$

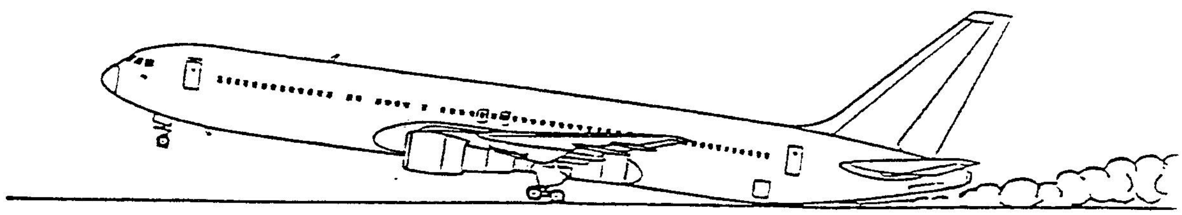
Demonstrate that if critical engine fails at $V_{MCG}$ during takeoff, airplane does not deviate more than 30 ft from projected ground track, and a safe, controllable takeoff can be completed.

<u>Procedure</u>

1. Abruptly cut engine power (at least one fuel cut) at $V_{MCG}$.
2. Maintain directional control with rudder only.
3. Perform at heaviest weight that may affect $V_1$, aft c.g.
4. Nose wheel free to caster.

EFFECT OF CROSSWIND

# Minimum Unstick Tests, $V_{mu}$



# MINIMUM UNSTICK TESTS PROCEDURE

1. Do $V_{MU}$ tests with AEO and OEI. May simulate OEI by reducing T/W and analytically adjusting performance to account for effects of lateral control on lift and drag.

2. Rotate to $V_{MU}$ attitude as early as possible in takeoff run.

3. After liftoff, maintain pitch attitude until out of ground effect.

4. Use forward c.g. limit.

5. For geometry limited airplanes

    -- AEO distance to 35 ft must be $\leq$ normal takeoff distance with same conditions.

    -- Maintain tail contact 50% of time from 96 to 100% of $V_{MU}$.

    -- Pitch attitude must not decrease from liftoff to 35 ft, speed must not increase more than 10%.

    -- Use critical T/W

# $V_R$ ABUSE TESTING

## OEI

1. Perform normal rotation at $V_R$ -5 kt after $V_E$ engine cut.

2. Airspeed at 35 ft must not be less than $V_2$ -5 kt.

## AEO

1. Use maximum sea level takeoff weight if possible.

2. Rotate 7% or 10 kt below $V_R$, whichever is less.

3. Rotate rapidly or rotate 2$^{\circ}$ beyond normal on liftoff. Minor tail strike is permissible.

4. Takeoff distance must not exceed 101% of scheduled distance.

5. Perform takeoff with elevator trim ±2 units in error, within takeoff trim band.

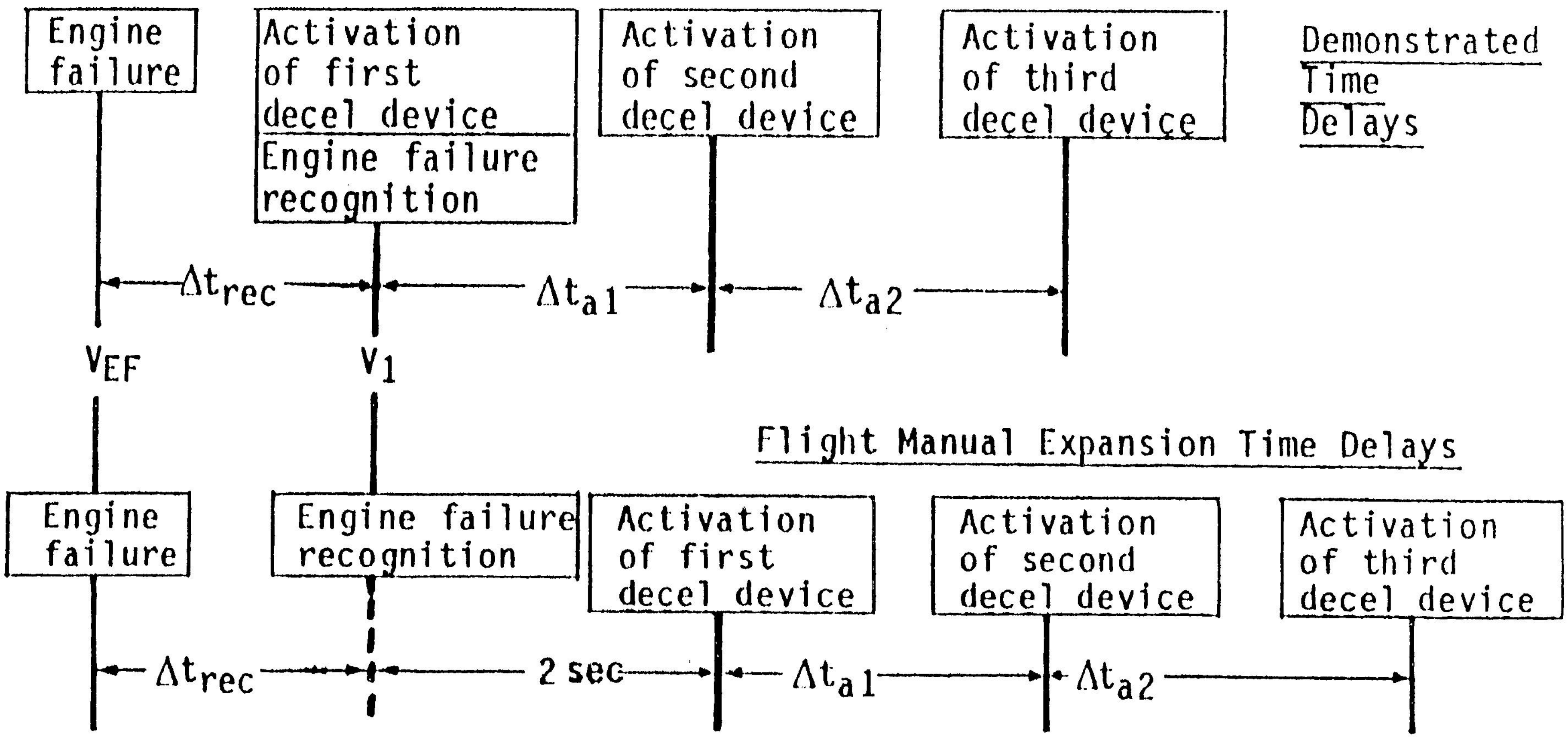
# ACCELERATE - STOP

- Six tests required covering range of takeoff gross weights and kinetic energy
- Reverse thrust not allowed
- Maximum energy rejected takeoff must be demonstrated at maximum TO weight

  -- after 3 mile taxi with 3 stops
  -- fires after rejected takeoff confined to tires, wheels and brakes
  -- no fire fighting for 5 minutes after the stop
  -- ability to taxi after stop not required

- Can conduct braking portion of RTO from a landing with certain provisions
- Time delays applied to flight manual data

## ACCELERATE-STOP TIME DELAYS
Post Amendment 25-42




(i) $\Delta t_{rec}$ - § 25.107 defines the relationship between $V_{EF}$ and $V_1$

# NORMAL AND OEI TAKEOFFS

These are performed to establish benchmarks to validate and fine tune analytical methods to construct AFM data.

1. Cover range of weights and density altitude.

2. No power adjustments after initial rolling setting. No power changes below 400 ft AGL.

3. Maintain constant airspeed $\geq V_2$ from 35 ft to 400 ft.

4. Must perform enough fuel cuts to verify manual throttle reduction.

5. May construct takeoff profiles from segments, but must be validated with a few continuous takeoffs.

# FAR 23 TAKEOFF TESTS

1. Must establish takeoff distance to 50 ft by test, either continuous or separate acceleration and climb segments.

2. Perform at maximum takeoff weight. Lower weights necessary only if presented in AFM as approved data.

3. Critical c.g. position (usual FWD)

4. Winds must not exceed 0.12 $V_{S_1}$ or 10 kt, whichever is lower. Prefer winds < 5 kt.

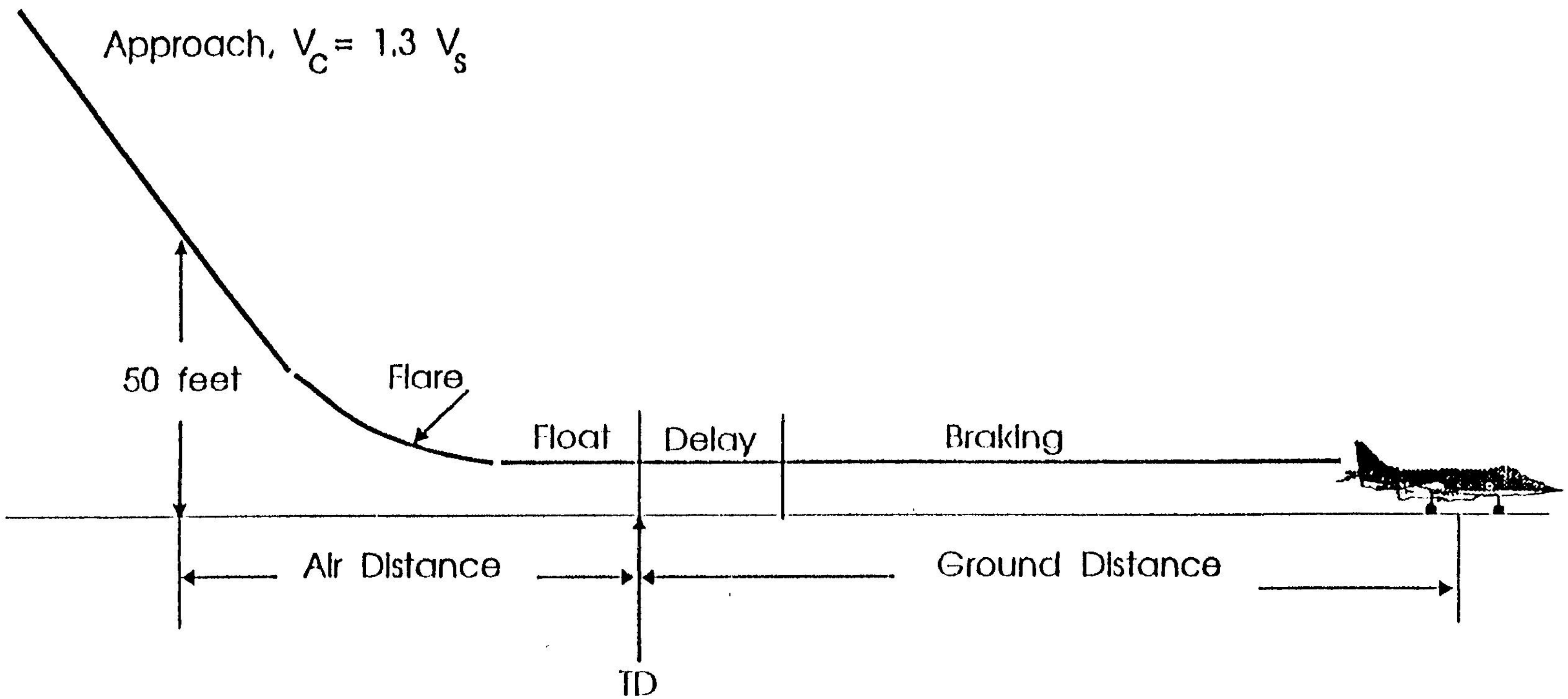
# INSTRUMENTATION

- Space - time position system
- Airspeed
- Altitude
- Accelerations
- Pitch attitude
- Control positions
- Engine parameters
- Brake pressures
- Weather station

# 6

# Flight test determination of landing distance and go-around performance

# Landing Profile



# REQUIREMENTS
## Landing Distance

Total distance from 50 ft height to full stop

Steady approach speed to 50 ft height,

| | | |
|---|---|---|
| $V_{REF}$ must be | $\geq V_{MC}$ <br> and $\geq 1.3\ V_{SO}$ | normal, utility and acrobatic |
| | $\geq 1.05\ V_{MC}$ <br> $\geq 1.3\ V_{SO}$ | commuters |
| | $\geq V_{MCL}$ <br> $\geq 1.3\ V_{S}$ | FAR 25 |

| | |
|---|---|
| Constant configuration | FAR 23 |
| May change configuration | FAR 25 |

Only wheel brakes may be used for braking.

Changes in power, airspeed, and altitude below 50 ft in accordance with established procedures.

**§ 23.73 Reference landing approach speed.**

(a) For normal, utility, and acrobatic category reciprocating engine-powered airplanes of 6,000 pounds or less maximum weight, the reference landing approach speed, $V_{REF}$, must not be less than the greater of $V_{MC}$, determined in § 23.149(b) with the wing flaps in the most extended takeoff position, and 1.3 $V_{SO}$.

(b) For normal, utility, and acrobatic category reciprocating engine-powered airplanes of more than 6,000 pounds maximum weight, and turbine engine-powered airplanes in the normal, utility, and acrobatic category, the reference landing approach speed, $V_{REF}$, must not be less than the greater of $V_{MC}$, determined in § 23.149(c), and 1.3 $V_{SO}$.

(c) For commuter category airplanes, the reference landing approach speed, $V_{REF}$, must not be less than the greater of 1.05 $V_{MC}$, determined in § 23.149(c), and 1.3 $V_{SO}$.

[Doc. No. 27807, 61 FR 5187, Feb. 9, 1996]

**§ 23.75 Landing distance.**

The horizontal distance necessary to land and come to a complete stop from a point 50 feet above the landing surface must be determined, for standard temperatures at each weight and altitude within the operational limits established for landing, as follows:

(a) A steady approach at not less than $V_{REF}$, determined in accordance with § 23.73 (a), (b), or (c), as appropriate, must be maintained down to the 50 foot height and—

(1) The steady approach must be at a gradient of descent not greater than 5.2 percent (3 degrees) down to the 50-foot height.

(2) In addition, an applicant may demonstrate by tests that a maximum steady approach gradient steeper than 5.2 percent, down to the 50-foot height, is safe. The gradient must be established as an operating limitation and the information necessary to display the gradient must be available to the pilot by an appropriate instrument.

(b) A constant configuration must be maintained throughout the maneuver.

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

(d) It must be shown that a safe transition to the balked landing conditions of § 23.77 can be made from the conditions that exist at the 50 foot height, at maximum landing weight, or at the maximum landing weight for altitude and temperature of § 23.63 (c)(2) or (d)(2), as appropriate.

(e) The brakes must be used so as to not cause excessive wear of brakes or tires.

(f) Retardation means other than wheel brakes may be used if that means—

(1) Is safe and reliable; and

(2) Is used so that consistent results can be expected in service.

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

[Amdt. 23-21, 43 FR 2318, Jan. 16, 1978, as amended by Amdt. 23-34, 52 FR 1828, Jan. 15, 1987; Amdt. 23-42, 56 FR 351, Jan. 3, 1991; Amdt. 23-50, 61 FR 5187, Feb. 9, 1996]

**§ 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 stabilized approach, with a calibrated airspeed of not less than 1.3 $V_S$ or $V_{MCL}$, whichever is greater, 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 pressures 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.

Doc. No. 5066, 29 FR 18291, Dec. 24, 1964, as amended by Amdt. 25-72, 55 FR 29774, July 20, 1990; Amdt. 25-84, 60 FR 30749, June 9, 1995]

# PROCEDURE - LANDING

FAR 23

- Steady, stabilized approach to 50 ft height
- Smooth flare to touchdown
- Glideslope $\leq$ 3 deg
- Normal pilot reaction times
- Wind < 10 kt
- Smooth, hard-surface runway
- Maximum landing weight
- Other weights if credit to be taken in AFM

# PROCEDURE - LANDING

## FAR 25

### Airborne Distance

1. Analytical: $D_A = 1.55 (V_{REF} - 80)^{1.35} + 800$

   $V_{REF}$ ~ KTAS
   $V_{TD} = V_{REF}$ - 3 knots

2. Test: Stabilized approach prior to 50 ft

   Average glideslope -3 deg

   $V_{REF}$ at 50 ft height

   No nosedown control after 50 ft, only power reduction

   Touchdown rate of descent average 6 fps

   At least 6 landing tests covering landing weight range

Airborne Distance (con't)

3. Regression analysis of test data

Applicant may perform 12 to 40 landings to establish airborne distance as a function of descent rate at 50 ft. Then airborne distance may be based on 3.5 deg approach angle and sink rate of 8 ft/sec at touchdown.

Target speed is $V_{REF}$

No data allowed for angles greater than 3.5 deg or sink rates at touchdown > 8 ft/sec.

May use autoland for up to half of test landings.

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# REGRESSION ANALYSIS METHOD

Parametric Analysis Data Reduction. The following is an acceptable method of converting the test data to a mathematical model for the parametric analysis method of air distance described in paragraph b(3).

Test Data for Each Test Point:

$R/S_{50}$ = Rate of sink at 50 ft. above landing surface, Ft/Sec
$R/S_{TD}$ = Rate of sink at touchdown, Ft/Sec
$V_{50}$ = True airspeed at 50 ft. above landing surface, Ft/Sec
$V_{TD}$ = True airspeed at touchdown, Ft/Sec
$t$ = Air time 50 ft. to touchdown, Sec

The multiple linear regression analysis as outlined below is used to solve for the constant of the two independent variable equation:

$$50/t = a+b(R/S_{50})+(c)(R/S_{TD})$$

To maintain the same units for all variables, the dependent variable is chosen as 50/t.

The test values of all the test points, 1 through n, are processed as follows, where n equals the number of test points:

$$R1 = \sum_1^n R/S_{50}$$

$$R2 = \sum_1^n (R/S_{50})^2$$

$$R3 = \sum_1^n R/S_{TD}$$

$$R4 = \sum_1^n (R/S_{TD})^2$$

$$R5 = \sum_1^n (R/S_{50})(R/S_{TD})$$

$$R6 = \sum_1^n (50/t)$$

$$R7 = \sum_1^n (R/S_{50})(50/t)$$

$$R8 = \sum_1^n (R/S_{TD})(50/t)$$

$$R9 = (n)(R2)-(R1)^2$$

# REGRESSION ANALYSIS METHOD (CON'T)

R10 = (n)(R8)-(R3)(R6)

R11 = (n)(R5)-(R1)(R3)

R12 = (n)(R7)-(R1)(R6)

R13 = (n)(R4)-$(R3)^2$

c = ((R9)(R10)-(R11)(R12))/((R9)(R13)-$(R11)^2$)

b = ((R12)-(c)(R11))/R9

a = ((R6)-(b)(R1)-(c)(R3))/n

In the same manner, determine the values of the constants, a, b, and c, in an equation for speed reduction between 50 ft. and touchdown by replacing 50/t with ($V_{50}/V_{TD}$) for each test run.

After determining the values of the constants, the two equations are used to calculate the time from 50 ft. to touchdown and $V_{50}/V_{TD}$ for the desired conditions of 3.5 degrees flight path and $R/S_{TD}$ = 8ft/Sec. The $R/S_{50}$ is calculated from the approach path and $V_{50}$.

After $V_{TD}$ is determined, the air distance may be determined for average speed and t.

Example:

Test Data:

| Run | $R/S_{50}$ | $R/S_{TD}$ | $V_{50}$ | $V_{TD}$ | t |
|---|---|---|---|---|---|
| 1 | 13.4 | 6.1 | 219 | 214 | 5.6 |
| 2 | 10.9 | 1.8 | 223 | 218 | 8.5 |
| 3 | 7.9 | 5.8 | 209 | 201 | 7.4 |
| 4 | 8.3 | 2.3 | 213 | 206 | 9.6 |
| 5 | 9.8 | 4.1 | 218 | 212 | 7.5 |

Results:

$50/t = 1.0432 + .3647\ R/S_{50} + .4917\ R/S_{TD}$

$V_{50}/V_{TD} = 1.05508 - .003198\ R/S_{50} + .001684\ R/S_{TD}$

For conditions of $V_{50}$ = 220, flight path = 3.5 degrees, $R/S_{TD}$ = 8.0 the resultants are:

$R/S_{50}$ = 13.43
t = 5.063 sec.

$V_{50}/V_{TD}$ = 1.0256
Air Distance = 1100 ft.

# TRANSITION AND STOPPING DISTANCE PROCEDURE

1. Must be based on tests.

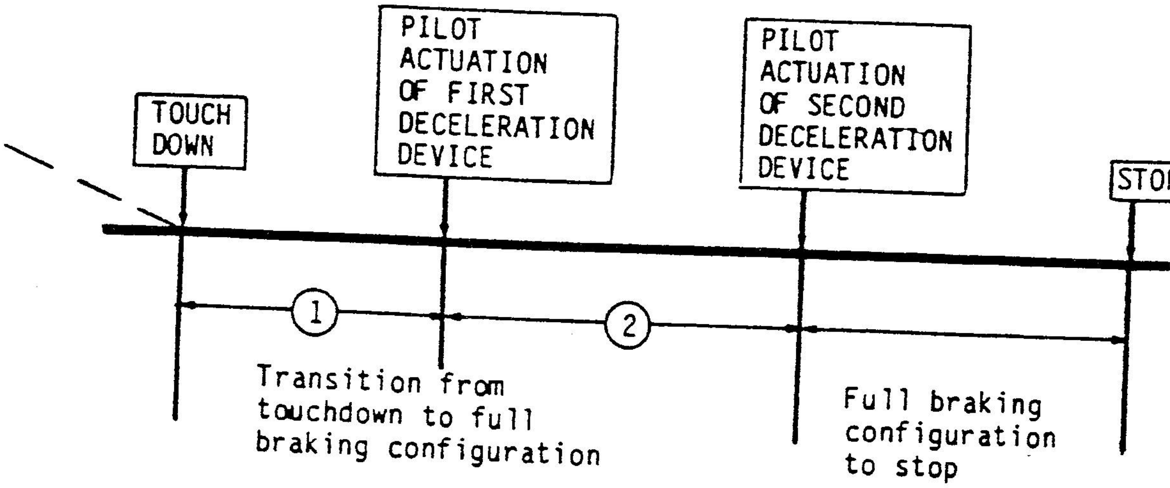
2. If data are available, two landings are required for each configuration to verify analysis. Otherwise, you must do a minimum of six in primary configuration.

3. Must perform six consecutive landings on same wheels, tires, and brakes with no failures until after sixth landing to demonstrate no excessive wear in service. Should cover weight range.

4. No reverse thrust may be used.

È stata cambiata, prima scendevano fino a 16 ft/sec di velocità al TD - Una volta la parte di dietro di un MD80 è saltata (si è rotta)

# LANDING TIME DELAYS




①,② Flight test measured average or 1 second, whichever is longer

### § 23.77 Balked landing.

(a) Each normal, utility, and acrobatic category reciprocating engine-powered airplane at 6,000 pounds or less maximum weight must be able to maintain a steady gradient of climb at sea level of at least 3.3 percent with—

(1) Takeoff power on each engine;

(2) The landing gear extended;

(3) The wing flaps in the landing position, except that if the flaps may safely be retracted in two seconds or less without loss of altitude and without sudden changes of angle of attack, they may be retracted; and

(4) A climb speed equal to $V_{REF}$, as defined in § 23.73(a).

(b) Each normal, utility, and acrobatic category reciprocating engine-powered airplane of more than 6,000 pounds maximum weight and each normal, utility, and acrobatic category turbine engine-powered airplane must be able to maintain a steady gradient of climb of at least 2.5 percent with—

(1) Not more than the power that is available on each engine eight seconds after initiation of movement of the power controls from minimum flight-idle position;

(2) The landing gear extended;

(3) The wing flaps in the landing position; and

(4) A climb speed equal to $V_{REF}$, as defined in § 23.73(b).

(c) Each commuter category airplane must be able to maintain a steady gradient of climb of at least 3.2 percent with—

(1) Not more than the power that is available on each engine eight seconds after initiation of movement of the power controls from the minimum flight idle position;

(2) Landing gear extended;

(3) Wing flaps in the landing position; and

(4) A climb speed equal to $V_{REF}$, as defined in § 23.73(c).

[Doc. No. 27807, 61 FR 5187, Feb. 9, 1996]

### § 25.119 Landing climb: All-engine-operating.

In the landing configuration, the steady gradient of climb may not be less than 3.2 percent, with—

(a) The engines at the power or thrust that is available eight seconds after initiation of movement of the power or thrust controls from the minimum flight idle to the go-around power or thrust setting; and

(b) A climb speed of not more than 1.3 $V_S$.

[Doc. No. 5066, 29 FR 18291, Dec. 24, 1964, as amended by Amdt. 25-84, 60 FR 30749, June 9, 1995]

# GO-AROUND CLIMB PERFORMANCE

**FAR 23.77** **Normal, utility, acrobatic MGW < 6000 lb, reciprocating engine:**

Sea level climb gradient ≥ 3.3% with
- Takeoff power, AEO
- Gear down
- Landing flaps (may be retracted)
- $V_{REF}$

**Normal, utility, acrobatic, MGW > 6000 lb or turbine engine:**

Climb gradient ≥ 2.5 % with
- Power available 8 sec after throttle advance from flight idle, AEO
- Landing configuration
- $V_{REF}$

**Commuter:**

Climb gradient ≥ 3.2% with
- Power available 8 sec after throttle advance from flight idle, AEO
- Landing configuration
- VREF

**FAR 25.119** Climb gradient ≥ 3.2%
- Power available 8 sec after throttle advance from flight idle
- Landing configuration
- $V \leq 1.3\ V_S$

# CRITICAL DATA

- Position in space
- Accelerations
- Airplane attitude
- Airspeed, Altitude
- Angle of attack, Sideslip
- Control positions
- Engine parameters
- Braking forces, pressures
- Weight on wheels