5 Performance of Multi-engine Aeroplanes

Not Certified under FAR/CS 25 (Light Twin) Performance Class B

5.1 General

Aeroplanes that are not certified under JAR/FAR 25 must be certified under another regulation. Usually it will be JAR/FAR 23. There are two main category multi-engine aeroplanes that are certified under JAR/FAR 23:

- Aeroplanes in the normal, utility and aerobatic categories that have a seating configuration, excluding the pilot seat(s), of nine or fewer and a maximum certificated take-off weight of 5670 kg (12 500 lb) or less
- Propeller-driven twin-engined aeroplanes in the commuter category that have a seating configuration, excluding the pilot seat(s), of nineteen or fewer and a maximum certificated take-off weight of 8618 kg (19000 lb) or less.

The performance class B requirements in JAR-OPS 1 are applicable to aeroplanes that belong to the first category. The performance class B requirements are also applicable to commuter category aeroplanes that have a seating configuration, excluding the pilot seat(s), of nine or fewer and a maximum certificated take-off weight of 5670 kg (12 500 lb) or less.

For commuter category aeroplanes that have a seating configuration, excluding the pilot seat(s), of more than nine, and a maximum certificated take-off weight of more than 8618 kg (19 000 lb), the performance class A requirements in JAR-OPS 1 are applicable.

5.2 Definitions of Terms and Speeds used for MEP - Take-Off

5.2.1 Take-Off Distance (Required)

The distance required to take-off and climb to a screen height of 50 ft.

5.2.2 Critical Engine

An engine failure on a multi-engine aeroplane will cause a yawing moment, due to the asymmetrical thrust situation it creates. The yawing moment is the product of the lateral distance from the fuselage centreline to the engine's thrust vector. This thrust vector is, when flying at low speeds and high angles of attack, displaced to the left or right of the propeller centreline, depending on the direction of propeller rotation. The reason is that the propeller disc is not perpendicular to the air stream.

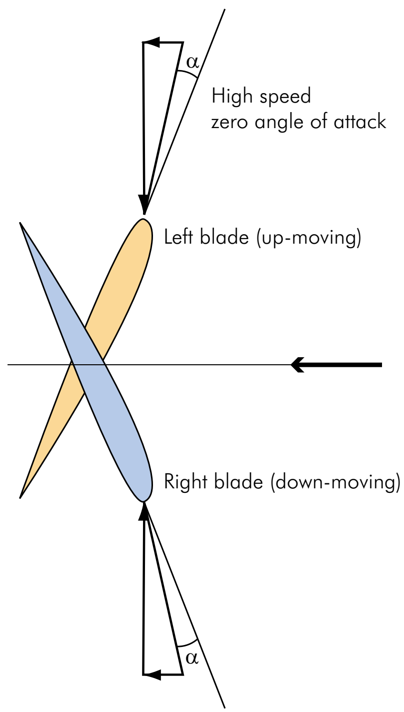


Fig. PE 5.1 Movement of thrust line of propeller

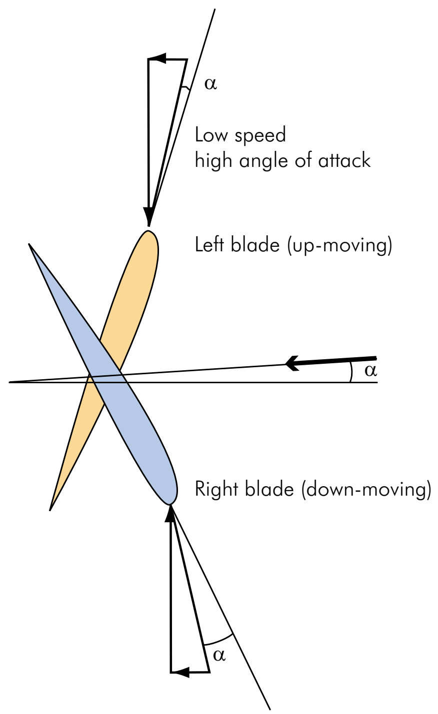


Fig. PE 5.2 Movement of thrust line of propeller

For a clockwise-rotating engine the thrust line is displaced to the right of the propeller centreline due to the fact that the down-moving blade (right side) has a greater angle of attack than the up-moving blade, *see fig. PE 5.1 and fig. PE 5.2.*

The engine whose failure would most adversely affect the performance or handling qualities of the aircraft is called the critical engine.

The critical engine for a twin propeller aircraft with clockwise-rotating engines is thus the left engine, *see fig. PE 5.3.*

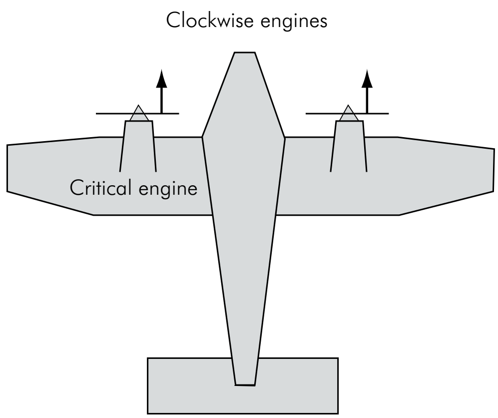


Fig. PE 5.3 Critical engine

5.2.3 Minimum Control Speed V_{MC}

The minimum control speed, V_{MC}, is the calibrated airspeed at which, when the critical engine is suddenly made inoperative, it is possible to maintain control of the aeroplane, and thereafter maintain straight flight at the same speed with an angle of bank of not more than 5°.

V_{MC} for take-off must not exceed 1.2 V_{S1}. For all aeroplanes except piston engined aeroplanes of 2730 kg or less V_{MC} must also be determined for the landing configuration. The aerodynamic forces created by the deflection of control surfaces increases with speed.

In flight the rudder force must be large enough to overcome the yawing moment created by a critical engine failure. The lowest speed at which the rudder force is large enough is the minimum control speed. The value of V_{MC} depends on the engine thrust value, thus it will be a higher speed at higher thrusts, i.e. at low altitudes and low temperatures.

5.2.4 Rotation Speed

For multi-engined aeroplanes certified under JAR 23, the rotation speed must not be less than the greater of 1.05 V_{MC} and 1.10 V_{S1}.

5.2.5 Clear 50 ft Speed

The speed at 50 ft must not be less than the highest of:

- A speed that is shown to be safe for continued flight (or land-back if applicable) under all reasonably expected conditions, including turbulence and complete failure of the critical engine
- 1.10 V_{MC}
- 1.20 V_{S1}.

5.3 Regulations - Take-Off MEP

5.3.1 Take-Off

a) An operator shall ensure that the take-off mass does not exceed the maximum take-off mass specified in the Aeroplane Flight Manual for the pressure altitude and the ambient temperature at the aerodrome at which the take-off is to be made.

b) An operator shall ensure that the unfactored take-off distance, as specified in the Aeroplane Flight Manual does not exceed:

- When multiplied by a factor of 1.25, the take-off run available; *see fig PE 5.4* or
- When stopway and/or clearway is available, the following;
  - the take-off run available
  - when multiplied by a factor of 1.15, the take-off distance available; and

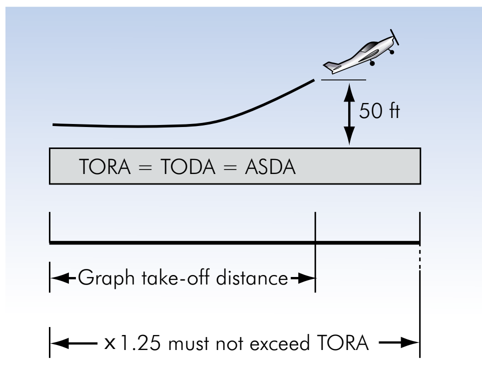


Fig. PE 5.4 Unfactored take-off distance - no stopway or clearway

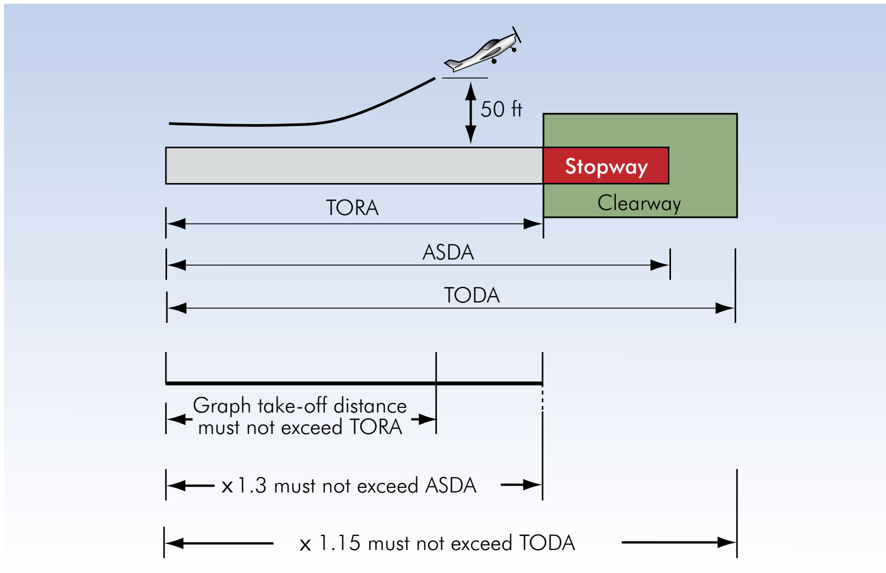


Fig. PE 5.5 Unfactored take-off distance - with clearway and/or stopway

- when multiplied by a factor of 1.3, the accelerate-stop distance available, *see fig PE 5.5*.

c) When showing compliance with sub-paragraph (b) above, an operator shall take account of the following:

- The mass of the aeroplane at the commencement of the take-off run
- The pressure altitude at the aerodrome
- The ambient temperature at the aerodrome
- The runway surface condition and the type of runway surface
- The runway slope in the direction of take-off and
- Not more than 50% of the reported headwind component or not less than 150% of the reported tailwind component.

5.3.2 Take-Off Performance Correction Factors

Unless otherwise specified in the Aeroplane Flight Manual or other performance or operating manuals from the manufacturers, the variables affecting the take-off performance and the associated factors that should be applied to the Aeroplane Flight Manual data are shown in *table PE 5.1.*

Surface type	Condition	Factor
Grass (on firm soil) up to 20 cm long	Dry	x 1.20
	Wet	x 1.30
Paved	Wet	x 1.00

Table PE 5.1 Surface/conditions corrections

Notes

- The soil is firm when there are wheel impressions but no rutting

- When taking off on grass with a single engined aeroplane, care should be taken to assess the rate of acceleration and consequent distance increase
- When making a rejected take-off on very short grass which is wet, and with a firm subsoil, the surface may be slippery, in which case the distances may increase significantly.

5.3.3 Take-Off Performance Contaminated Runways

Due to the inherent risks, operations from contaminated runways are inadvisable, and should be avoided whenever possible. Therefore, it is advisable to delay the take-off until the runway is cleared. Where this is impracticable, the commander should also consider the excess runway length available including the criticality of the overrun area.

5.3.4 Runway Slope

Unless otherwise specified in the Aeroplane Flight Manual, or other performance or operating manuals from the manufacturers, the take-off distance should be increased by 5% for each 1% of upslope except that correction factors for runways with slopes in excess of 2% require the acceptance of the Authority. No factorisation is permitted for downslope.

5.4 Specimen Aeroplane - Data Sheets Take-Off

5.4.1 General Considerations

The specimen aeroplane is a low wing monoplane with retractable undercarriage. It is powered by twin, reciprocating, engines (both of which are supercharged). These drive counter-rotating, constant speed propellers. The aeroplane, which is not certified under JAR/FCL 25, is a landplane and is classified in Performance Class B.

5.4.2 General Requirements

This class of aeroplane includes all propeller-driven aeroplanes having 9 or less passenger seats and a maximum take-off weight of 5700 kg or less. Performance accountability for engine failure, on a multi engine aeroplane in this class, need not be considered below a height of 300 ft.

5.4.3 Aeroplane Limitations: Structural Limitations

Maximum Take-off Mass	4750 lb
Maximum Landing Mass	4513 lb

Runway Crosswind Limitation
Maximum Demonstrated crosswind 17 kt.

5.4.4 Take-Off

The take-off requirements for multi-engined Class B aeroplane (other than those in the commuter category) are the same as for single engined aeroplane with the addition of requirements for clearance of obstacles after take-off.

The requirements for commuter category aeroplane are more similar to those for Class A aeroplane, requiring consideration of engine failure on take-off and accelerate-stop performance.

There are no requirements for the accelerate-stop distance required, (for non-commuter aeroplane) but the Aeroplane Flight Manual may present data for this distance.

To determine the maximum mass for take-off, it is necessary to consider:

- The mass for altitude and temperature (gradient requirement)
- The take-off distance requirement
- The obstacle clearance requirement.

5.4.5 Take-Off Distance Requirements

Other than for commuter category aeroplanes, these are the same as for the single engined Class B aeroplane.

The gross take-off distance required is the distance from the start of the take-off to a point 50 ft above the take-off surface, with take-off power on each engine, rotating at V_R and achieving the specified speed at the screen height.

5.5 Use of Take-Off Graphs MEP

There are two sets of take-off graphs: one for a "normal" take-off with 0° flap and the other for a "maximum effort" (short field) take-off with 25° flap. Each set comprises two graphs, one for determining the take-off run and take-off distance, the other for calculating the accelerate-stop distance, *see fig. PE 5.6, to fig. PE 5.9.*

5.5.1 Distance Calculation Procedure

To determine the distance used for take-off:

a) Select the appropriate graph.

b) Enter the left carpet at the OAT. Travel vertically to the aerodrome pressure altitude.

c) From this point proceed horizontally right to the weight reference line. Parallel the grid lines to the appropriate take-off weight.

d) Continue horizontally right to the wind component reference line and parallel the grid lines to the wind component input.

e) To read the appropriate distance.

  i) Continue horizontally from the wind component for TOR and ASD.

  ii) For take-off distance continue to the ground roll reference line then parallel the grid lines.

f) Factorise for surface and slope.

Example

Normal Take-off *(see fig. PE 5.6)*

Aerodrome Pressure Altitude	2000 ft
Ambient Temperature	+ 21°C
Take-off Weight	3969 lb
Wind Component	9 kt Head
Runway Slope	1.5 % Uphill
Runway Surface	Wet Grass
Aerodrome Field Lengths	Unbalanced.

Calculate Take-off Distance Required.

Solution

Graphical Distance	1650 ft
Surface Factor =	× 1.3
Slope Factor	× 1.075
Take-off Distance =	2306 ft
Regulatory Factor =	× 1.15.

Take-Off Distance Required **2652 ft**.

5.5.2 Weight Calculation

To calculate the field-length limited take-off weight it is necessary to apply the requirements of JAR-OPS. Only the take-off distance graph is used but the right vertical axis is entered with shortest available de-factored distance. The factors to be considered are those of slope, surface condition and regulation.

Weight Calculation Procedure.
(See fig. PE 5.6 and fig. PE 5.8)

1) Enter the left carpet at the ambient temperature. Move vertically to the aerodrome pressure altitude.
2) From this point, travel horizontally right to the weight reference line. Mark this position with a pencil.
3) Enter the right vertical axis at the de-factored distance. Parallel the grid lines to the ground roll reference line.
4) Now travel horizontally left to the appropriate wind component input. Parallel the grid lines to the wind component reference line.
5) From this point draw a horizontal line left through the weight grid.
6) From the position marked in 2 above, parallel the grid lines to intersect the horizontal line from 5 above.
7) At the intersection, drop vertically to the carpet to read the field length limited TOW.

Example 1

Maximum Effort Take-off (Short Field)
(see fig. PE 5.8)

Aerodrome Pressure Altitude	2000 ft
Ambient Temperature	+ 30° C
Wind Component	5 kt Tail
Runway Slope	2 % Uphill
Surface Type	Grass
Surface Condition	Dry

TORA: 2400 ft ASDA: 2500 ft TODA: 2600 ft.

Calculate

The field length limited take-off weight.

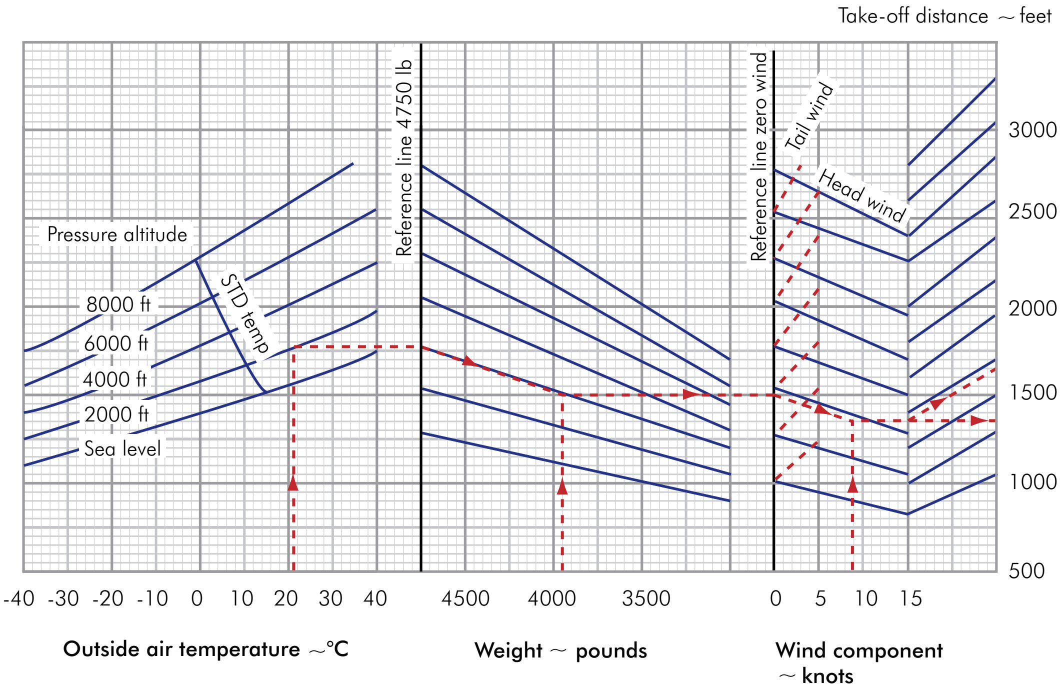
Solution *(see table PE 5.3)*

Field Length Limited TOW 4000 lb
using 1457 ft.

NORMAL PROCEDURE TAKE-OFF

Associated conditions:

2800 rpm and 40 inches MAP - paved - level - dry runway - liftoff at 79 KIAS - barrier at 79 KIAS - flaps 0° - cowl flaps 1/2 open



Example:

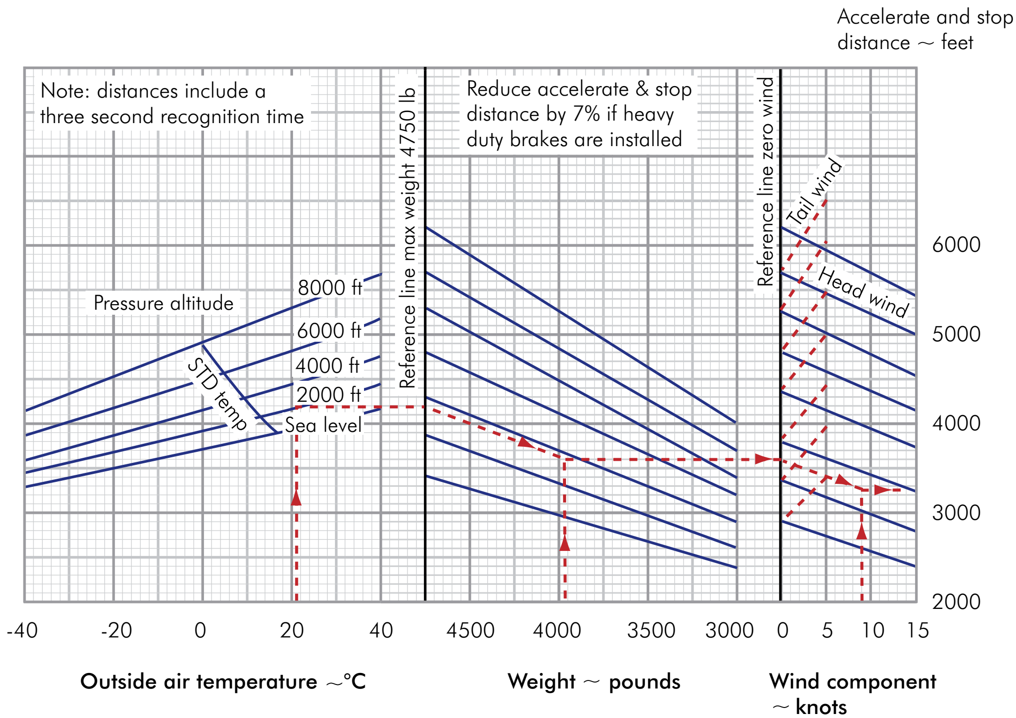
OAT ....21°C
Pressure altitude..............................2000 ft
Gross weight...................................3969 lb
Head wind.....................................9 knots
Take-off ground roll..........................1350 ft
Take-off distance over 50 ft barrier.....1650 ft

Fig. PE 5.6 Normal procedure take-off

ACCELERATE AND STOP DISTANCE

Associated conditions:

Full power before brake release - standard wheels - tires and brakes - wing flaps 0° - abort speed 79 KIAS - both throttles closed at engine failure - maximum breaking - paved - level - dry runway - cowl flaps 1/2 open



Example:

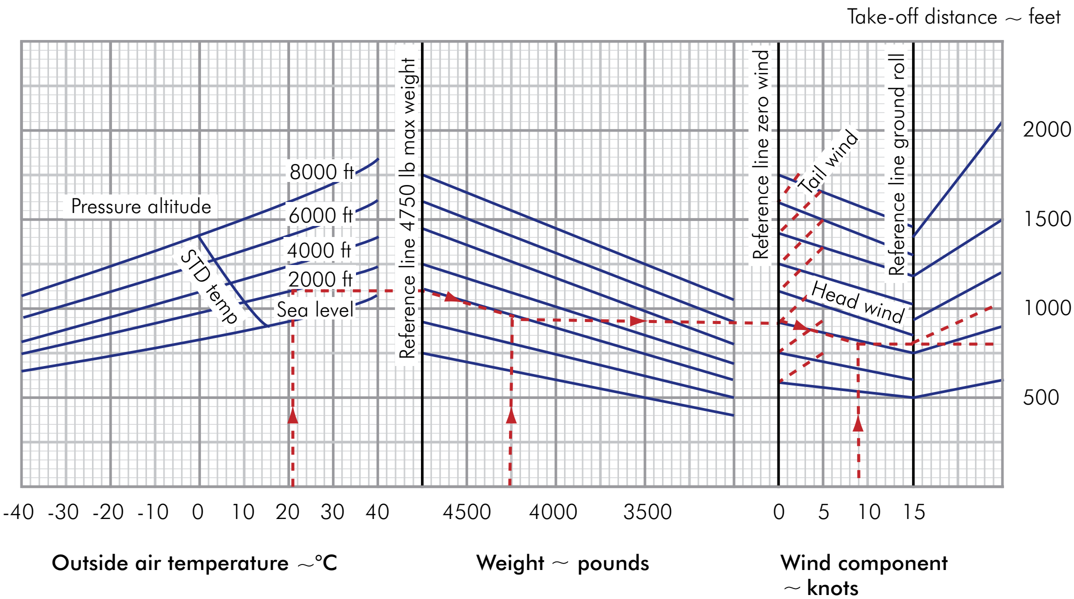
OAT ....21°C
Pressure altitude...............................2000 ft
Gross weight...................................3969 lb
Head wind.....................................9 knots
Accelerate & stop distance................3260 ft

Fig. PE 5.7 Accelerate - stop distance - normal take-off

MAXIMUM EFFORT TAKE-OFF - FLAPS 25°

Associated conditions:

2800 rpm and 40 inches MAP before brake release -
paved - level - dry runway - liftoff at 64 KIAS -
barrier at 66 KIAS - flaps 25° - cowl flaps 1/2 open



Example:

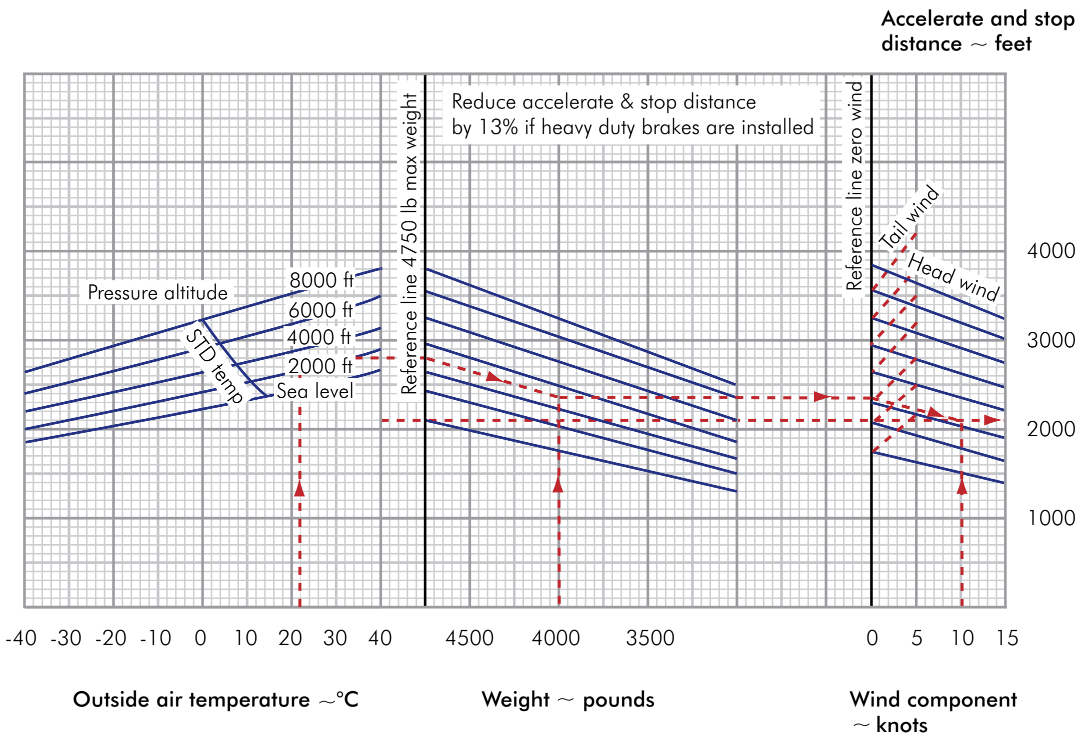
OAT ....21°C
Pressure altitude..............................2000 ft
Gross weight...................................4250 lb
Head wind......................................9 knots
Take-off ground roll..........................800 ft
Take-off distance over 50 ft barrier.....1040 ft

Fig. PE 5.8 Maximum effort take-off

ACCELERATE AND STOP DISTANCE

Associated conditions:

Full power before brake release - wing flaps 25° -
abort speed 64 KIAS - both throttles closed at engine failure -
maximum braking paved - level - dry runway - cowl flaps 1/2 open



Example:

OAT ....22°C
Pressure altitude...............................3000 ft
Gross weight....................................4000 lb
Head wind.......................................10 knots
Accelerate & stop distance.................2100 ft

Note:

Distance include a three second recognition time

Fig. PE 5.9 Accelerate stop distance - maximum effort