Safety Regulation Group

Civil Aviation Authority

CAP 698

CAA JAR-FCL Examinations

Aeroplane Performance Manual

Third Edition July 2006

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List of Effective Pages

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Contents

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Revision History

1st Edition **August 1999**

CAP 698, CAA JAR-FCL Examinations Performance Manual, was produced to support training and examinations in JAR-FCL Subject 032 - Performance for Aeroplanes.

2nd Edition **June 2001**

The manual was reissued to incorporate CAA House Style.

3rd Edition **July 2006**

This edition has been upgraded with digitised graphics. Definitions and conversions have been rationalised and known errors have been corrected.

3rd Edition (corrected) **September 2006**

Since the publication of the third edition, some errors and omissions have been identified. The corrections are as follows:

Section/Aircraft	Page(s)	Correction
2/SEP	1	Text of paragraph 2.1 corrected.
2/SEP	2	Correction to Example and Solution at paragraph 2.2.1.
3/MEP	5/8	Fig 3.2 and 3.4 – associated conditions; 'reaction time' corrected to 'recognition time'.
3/MEP	11	Fig 3.5 – ROC scale; '800' corrected to '500'.
3/MEP	13	Fig 3.6 – Associated conditions; 'Inoperative engine feathered' added.
3/MEP	21/23	Fig 3.9 and 3.10 – 'obstacle speed' corrected to 'barrier speed'.
3/MEP	23	Fig 3.10 – speed scale of barrier speed ; '90' changed to '82' and '66' changed to '68'.
4/MRJT	4	Fig 4.1 - At base of graph, 'crosswind component' added.
4/MRJT	41, 42, 43, 44	Figs 4.24, 4.25, 4.26 and 4.27; Max continuous thrust limit box; 'A/C Auto (High)' corrected to 'A/C OFF'.

The affected pages are identified by the word (corr.) after the page date.

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Section 1 General Notes

1 Introduction

Important Notice

1.1 The data sheets in this manual are produced to support training and examinations in JAR-FCL Subject 032 - Performance for Aeroplanes.

1.2 The data contained within these sheets are for **training and examination purposes only**. The data must not be used for any other purpose and, specifically, **are not to be used for the purpose of planning activities associated with the operation of any aeroplane in use now or in the future**.

2 Aircraft Description

2.1 The aeroplanes used in these data sheets are of generic types related to the classes of aeroplane on which the appropriate examinations are based.

2.2 Candidates must select the correct class of aeroplane for the question being attempted.

Generic Aeroplanes

Single-Engine Piston	certificated under CS 23 (Light Aeroplanes) Performance Class B	**SEP1**
Multi-Engine Piston	certificated under CS 23 (Light Aeroplanes) Performance Class B	**MEP1**
Medium-Range Jet Transport	certificated under CS 25 (Large Aeroplanes) Performance Class A	**MRJT1**

2.3 The same set of generic aeroplanes will be utilised in the following subjects:

- 031 - Mass and Balance - Aeroplanes
- 032 - Performance - Aeroplanes
- 033 - Flight Planning and Monitoring - Aeroplanes

3 Layout of Data Sheets

3.1 Each set of data sheets will consist of an introduction that will contain some pertinent information relating to the aircraft and the subject being examined. This data will include (but is not limited to) a list of abbreviations and some conversion factors.

3.2 This will be followed by a selection of graphs and/or tables that will provide coverage suitable for the syllabus to be examined. A worked example will accompany each graph/table and will demonstrate typical usage.

4 Definitions

Definitions given in italics are not given in ICAO, or JAA or EASA documentation but are in common use.

Altitude	The altitude shown on the charts is pressure altitude. This is the height in the International Standard Atmosphere at which the prevailing pressure occurs. It may be obtained by setting the sub-scale of a pressure altimeter to 1013 hPa (29.92 inches or 760 mm. of mercury).
Climb Gradient	*The ratio, in the same units of measurement, expressed as a percentage, as obtained from the formula:-* $\text{Gradient} = \frac{\text{Change in Height}}{\text{Horizontal Distance}} \times 100\%$
Elevation	The vertical distance of an object above mean sea level. This may be given in metres or feet.
Gross Height	*The true height attained at any point in the take-off flight path using gross climb performance. Gross height is used for calculating pressure altitudes for purposes of obstacle clearance and the height at which wing flap retraction is initiated.*
Gross Performance	*The average performance that a fleet of aeroplanes should achieve if satisfactorily maintained and flown in accordance with the techniques described in the manual.*
Height	The vertical distance between the lowest part of the aeroplane and the relevant datum.
International Standard Atmosphere (ISA)	A structure of assumed conditions relating to the change of pressure, temperature and density with height in the atmosphere.
IAS	The airspeed is the reading obtained on a pitot-static airspeed indicator calibrated to reflect standard adiabatic compressible flow at mean sea level.
Maximum Structural Landing Mass	The maximum permissible total mass of an aeroplane on landing (under normal circumstances).
Maximum Structural Take-Off Mass	The maximum permissible total mass of an aeroplane at the start of the take-off run.

Net Height	*The true height attained at any point in the take-off flight path using net climb performance. Net height is used to determine the net flight path that must clear all obstacles by the statutory minimum to comply with the Operating Regulations.*
Net Performance	*Net performance is the gross performance diminished to allow for various contingencies that cannot be accounted for operationally e.g., variations in piloting technique, temporary below average performance, etc. It is improbable that the net performance will not be achieved in operation, provided the aeroplane is flown in accordance with the recommended techniques.*
Outside Air Temperature (OAT or SAT)	The free air static (ambient) temperature.
Take-Off Mass (TOM)	The mass of an aeroplane, including everything and everyone contained within it, at the start of the take-off run.
TAS	The 'true airspeed' is the speed of the aeroplane relative to the undisturbed air.
Total Air Temperature (TAT)	The static air temperature plus adiabatic compression (ram) rise as indicated on the Total Air Temperature indicator.

N.B. Within these data sheets the term 'weight' should be considered to have the same meaning as 'mass'.

5 Conversions

The following conversions, based on those in ICAO Annex 5, are satisfactory for use in JAR-FCL examinations in 030 subjects.

5.1 Mass conversions

Pounds (lb) to Kilograms (kg)	lb x 0.454 = kg
Kilograms (kg) to Pounds (lb)	kg x 2.205 = lb

5.2 Volumes (Liquid)

Imperial Gallons to Litres (L)	Imp. Gall x 4.546 = Litres
US Gallons to Litres (L)	US Gall x 3.785 = Litres

5.3 Lengths

Feet (ft) to Metres (m)	Feet x 0.305 = Metres

5.4 Distances

Nautical mile (NM) to Metres (m)	NM x 1852.0 = Metres

Section 2 Data for Single-Engine Piston Aeroplane (SEP1)

1 General Considerations

1.1 Performance Classification

The specimen aeroplane is a low wing monoplane with retractable undercarriage. It is powered by a single reciprocating engine and a constant speed propeller.

The aeroplane, which is not certificated under CS/FAR 25, is a land-plane classified in Performance Class B.

1.2 General Requirements

An operator shall not operate a single-engine aeroplane:

a) At night.

b) In instrument meteorological conditions except under special visual flight rules.

c) Unless surfaces are available which permit a safe forced landing to be executed.

d) Above a cloud layer that extends below the relevant minimum safe altitude.

1.3 Aeroplane Limitations

Structural Limitations

Maximum Take-Off Mass	3650 lb
Maximum Landing Mass	3650 lb
Maximum Runway Cross Wind	17 kt

2 Take-Off

2.1 Requirements

The only take-off requirement for a single engined aeroplane is for the Field Length as detailed in paragraph 2.1.1 below. As explained in paragraph 3, there is no take-off climb requirement.

2.1.1 Field Length Requirements

a) When no stopway or clearway is available the take-off distance when multiplied by 1.25 must not exceed TORA.

b) When a stopway and/or clearway is available the take-off distance must:

i) not exceed TORA

ii) when multiplied by 1.3, not exceed ASDA

iii) when multiplied by 1.15, not exceed TODA

c) If the runway surface is other than dry and paved the following factors must be used when determining the take-off distance in a) or b) above:

Surface Type	Condition	Factor
Grass (on firm soil)	Dry	x 1.2
up to 20 cm Long	Wet	x 1.3
Paved	Wet	x 1.0

d) Take-off distance should be increased by 5% for each 1% upslope. No factorisation is permitted for downslope.

NOTE: The same surface and slope correction factors should be used when calculating TOR or ASD.

2.2 Use of Take-Off Graphs

There are two take-off distance graphs. One with flaps up (Figure 2.1) and the other with flaps approach (Figure 2.2). These graphs are used in exactly the same manner.

2.2.1 Distance Calculation

To determine the take-off distance:

a) Select the graph appropriate to the flap setting.

b) Enter at the OAT. Move vertically up to the aerodrome pressure altitude.

c) From this point, travel horizontally right to the mass reference line. Parallel the grid lines to the take-off mass input.

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

e) Proceed horizontally right to the obstacle reference line. Continue horizontally right to read ground roll distance or proceed parallel to the grid lines to read total distance to 50ft obstacle (TOD).

f) Factorise for surface and slope.

Example: Flaps Up

Aerodrome Pressure Altitude	5653 ft
Ambient Temperature	+15°C
Take-Off Mass	3650 lb
Wind Component	10 kt Head
Runway Slope	1.5% Uphill
Runway Surface	Grass
Runway Condition	Wet

Calculate: Take-Off Distance

Solution:

Graphical Distance	3450 ft
Surface Factor	x 1.3
Slope Factor	x 1.075
Take-Off Distance	4821 ft

ASSOCIATED CONDITIONS

POWER.................. TAKE-OFF POWER SET BEFORE BRAKE RELEASE
MIXTURE................ FULL RICH
FLAPS.................. UP
LANDING GEAR........... RETRACT AFTER POSITIVE CLIMB ESTABLISHED
COWL FLAPS............. OPEN
RUNWAY................. PAVED, LEVEL, DRY SURFACE

EXAMPLE

OAT................................ 15°C
PRESSURE ALTITUDE.................. 5653 ft
TAKE-OFF MASS...................... 3650 lb
HEAD WIND COMPONENT................ 10 kt

GROUND ROLL........................ 1900 ft
TOTAL DISTANCE OVER 50 ft OBSTACLE.... 3450 ft
TAKE-OFF SPEED AT:
ROTATION........................... 73 kt
50 ft.............................. 84 kt

MASS lb	TAKE-OFF SPEED kt	
	ROTATION	50 ft
3650	73	84
3600	72	83
3400	71	82
3200	70	80
3000	68	78
2800	65	75

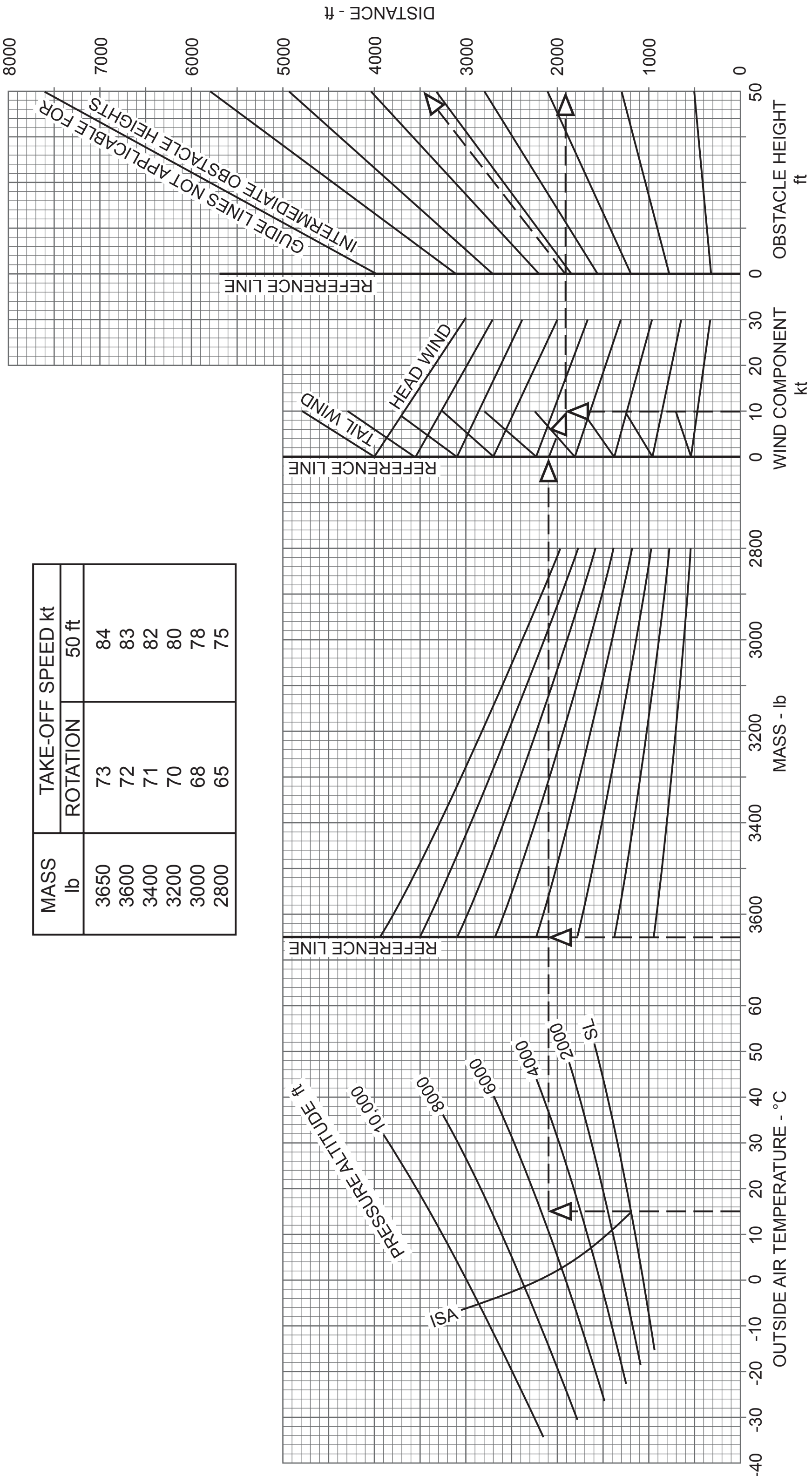

Figure 2.1 Take-Off Distance Flaps Up

2.2.2 Mass Calculation

To calculate the field length limited take-off mass 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.

a) Enter at the ambient temperature. Move vertically to the aerodrome pressure altitude.

b) From this point, travel horizontally right to the mass reference line. Mark this position with a pencil.

c) Enter the right vertical axis with the shortest available de-factored distance at the 50ft height. Parallel the grid lines down to the reference line.

d) Now travel horizontally left to the appropriate wind component input. Parallel the grid lines to the wind component reference line.

e) From this point, draw a horizontal line left through the mass grid.

f) From the position marked in b), above, parallel the grid lines to intersect the horizontal line from e), above.

g) At the intersection, drop vertically to read the field length limited TOW.

Example: Flaps Approach

Aerodrome Pressure Altitude	5653 ft
Ambient Temperature	+15°C
Wind Component	10 kt Head
Runway Slope	2% Uphill
Runway Surface	Grass
Runway Condition	Dry

TORA 4250 ft; ASDA 4470 ft; TODA 4600 ft

Calculate the Field Length Limited TOW.

	TORA	ASDA	TODA
Given Distances	4250 ft	4470 ft	4600 ft
Slope Factor	1.1	1.1	1.1
Surface/Condition Factor	1.2	1.2	1.2
Regulation Factor	1.0	1.3	1.15
De-factored Distance	3220 ft	2605 ft	3030 ft

Field Length Limited TOW 3530 lb Using 2605 ft

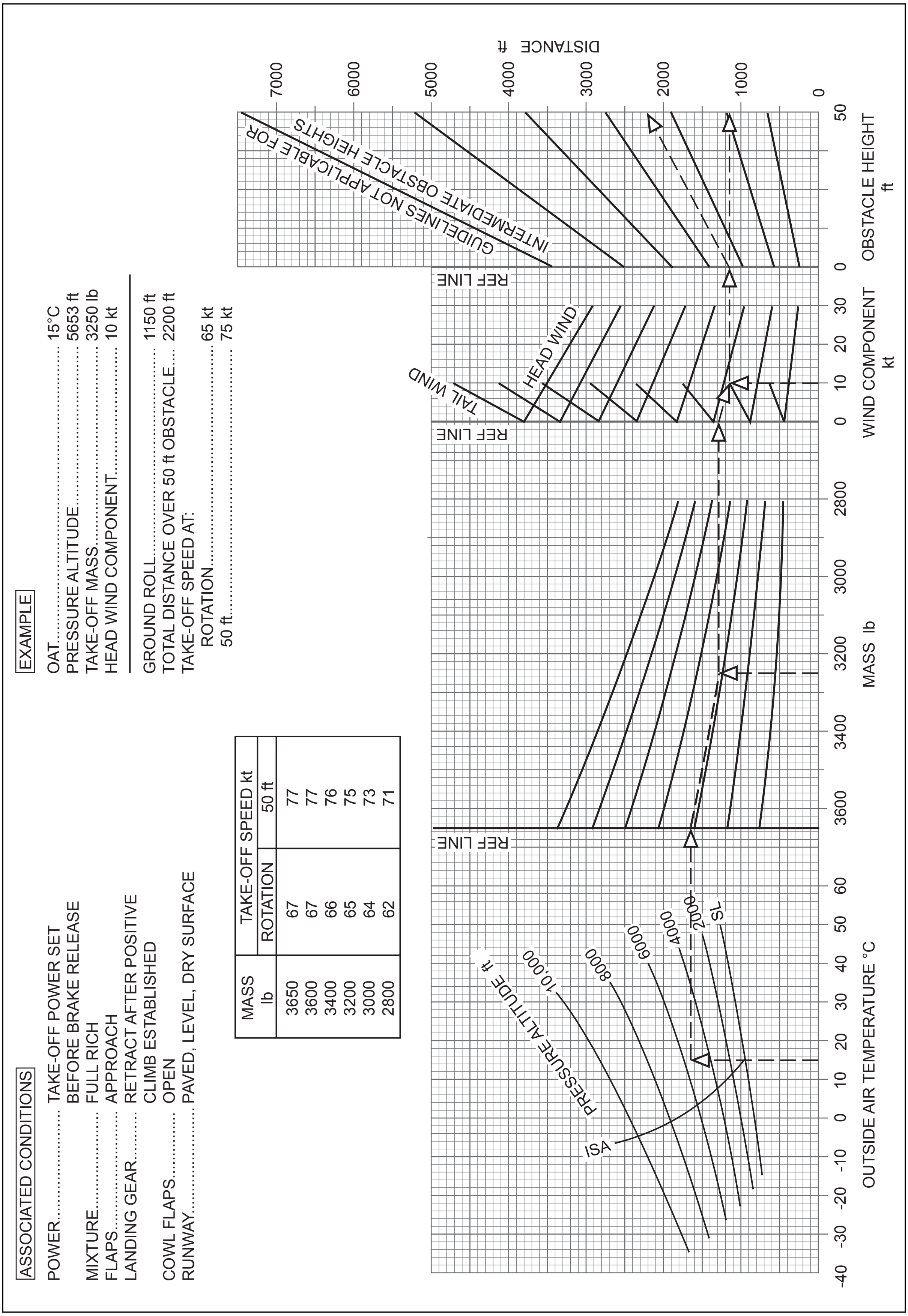

Figure 2.2 Take-Off Distance Flaps Approach

3 Take-Off Climb

3.1 Requirements

There are no obstacle clearance limits or minimum acceptable climb gradient required by JAR-OPS 1.

3.2 Use of Climb Graph

3.2.1 Climb Gradient and Rate of Climb.

To determine the climb gradient and rate of climb:

a) Use the navigation computer to calculate the TAS.
b) Enter the graph at the ambient temperature. Move vertically up to the pressure altitude.
c) From this point, travel horizontally right to the mass reference line. Parallel the grid lines to the appropriate mass input.
d) Now continue horizontally right to the first vertical axis to read the rate of climb. Continue horizontally to the TAS reference line.
e) Parallel the grid lines to intersect the TAS input then travel horizontally right to the right vertical axis to read the climb gradient.

Example:

Pressure Altitude	11500 ft
Ambient Temperature	-5°C
Weight	3600 lb

Solution:

Graphical ROC	515 fpm
TAS	120 kt
Climb Gradient	4.2%

3.2.2 Maximum Weight

To determine the maximum weight for a given gradient:

a) Enter the graph at the ambient temperature. Move vertically up to the Pressure Altitude.
b) From this point, travel horizontally right to the weight reference line and mark with a pencil.
c) Calculate the TAS using the Navigation Computer.
d) Enter the right vertical axis at the appropriate gradient and travel horizontally left to intercept the TAS calculated in c). From this point follow the grid lines to reach the reference line and draw a horizontal line through the weight grid.
e) From the pencil mark in b), above, parallel the grid lines to intersect the horizontal line drawn in d) above. Drop vertically to read the Climb-Limited Take-off weight.

Example:

Aerodrome Pressure Altitude	11000 ft
Ambient Temperature	+25°C
Gradient	4.2%

Solution:

TAS	125 kt
Maximum Weight	3360 lb

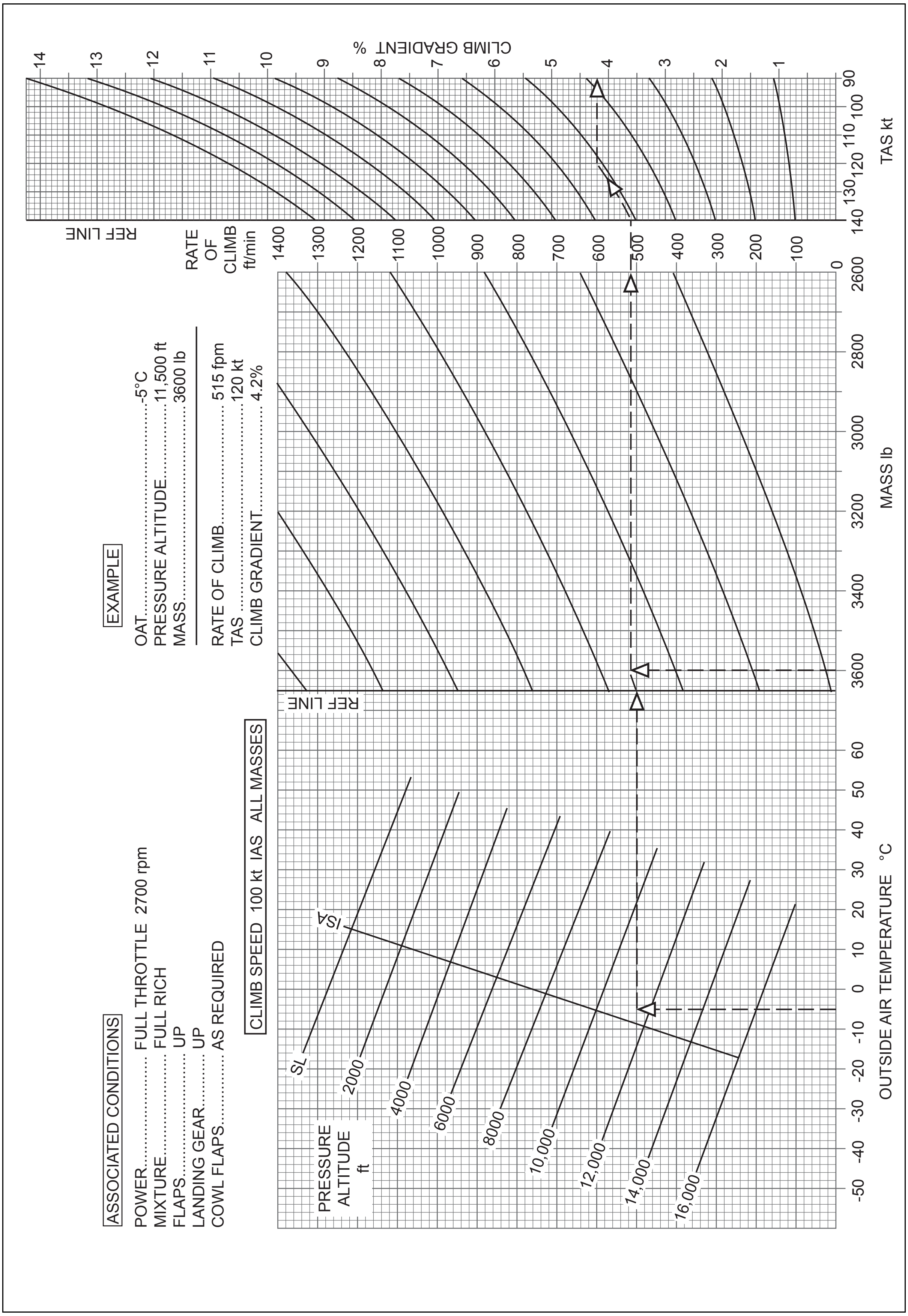

Figure 2.3 Climb

3.2.3 Distance to Reach given height.

To calculate the ground distance travelled in order to attain a given height above reference zero:

a) Convert the IAS 100 kt to a TAS, assume no position error.

b) Apply the wind component to the TAS to obtain the ground speed.

c) Determine the climb gradient from the graph.

d) Calculate the still air distance using the formula:

$$\text{Still Air Distance (ft)} = \frac{\text{Height Difference (ft)}}{\text{Gradient}} \times 100$$

e) Calculate ground distance using the formula:

$$\text{Ground Distance} = \text{Still Air Distance} \times \frac{\text{Groundspeed}}{\text{TAS}}$$

Example:

Aerodrome Pressure Altitude	4000 ft
Ambient Temperature	+30°C
Wind Component	30 kt tail
Take-Off Weight	3200 lb

Calculate the ground distance to reach 950 ft above reference zero from the end of TODR.

Solution:

100 kt IAS = 110 kt TAS

Groundspeed = 140 kt

Graph Gradient = 10.0%

$$\text{Still Air Distance} = \frac{900}{10.0} \times 100 = 9000 \text{ ft}$$

$$\text{Ground Distance} = 9000 \times \frac{140}{110} = 11455 \text{ ft} = 1.88 \text{ NM.}$$

4 En-Route

4.1 Requirements

The aeroplane may not be assumed to be flying above the altitude at which a rate of climb of 300 ft/min is attained.

The net gradient of descent, in the event of engine failure, shall be the gross gradient of descent increased by a gradient of 0.5%

5 Landing

5.1 Requirements

Field Length Requirements

a) The landing distance, from a screen height of 50 ft, must not exceed 70 % of the landing distance available, i.e. a factor of 1.43.

b) If the landing surface is grass up to 20 cm long on firm soil, the landing distance should be multiplied by a factor of 1.15.

c) If the METAR or TAF or combination of both indicate that the runway may be wet at the estimated time of arrival, the landing distance should be multiplied by a factor of 1.15.

d) The landing distance should be increased by 5% for each 1% downslope. No allowance is permitted for upslope.

e) The despatch rules for scheduled (planned) landing calculations are in JAR - OPS 1.550 (c).

5.2 Use of the Landing Field Length Graph

Distance Calculations

a) Enter at the ambient temperature. Move vertically to the aerodrome pressure altitude.

b) From this point, move horizontally right to the landing mass reference line. Parallel the grid lines to the appropriate landing mass input.

c) Continue from this intersection to the wind component reference line. Parallel the grid line to the appropriate wind component input.

d) Travel horizontally right to the ground roll reference line. Either continue horizontally to the right vertical axis to read the ground roll distance or parallel the grid lines to the right vertical axis to read the graphical distance.

e) Apply the surface and slope factors to the graphical distance to obtain the landing distance. Apply the regulatory factor to the landing distance to obtain the landing distance required.

Example: Normal Landing

Aerodrome Pressure Altitude	3965 ft
Ambient Temperature	+25°C
Landing Mass	3479 lb
Wind Component	10 kt Head
Runway Slope	1% down
Runway Surface	Grass
Runway Condition	Wet

Calculate Landing Distance Required

Solution:

Graphical Distance	1500 ft
Slope Correction Factor	x 1.05
Surface Correction Factor	x 1.15
Condition Correction Factor	x 1.15
Regulatory Factor	x 1.43
Landing Distance Required =	2979 ft

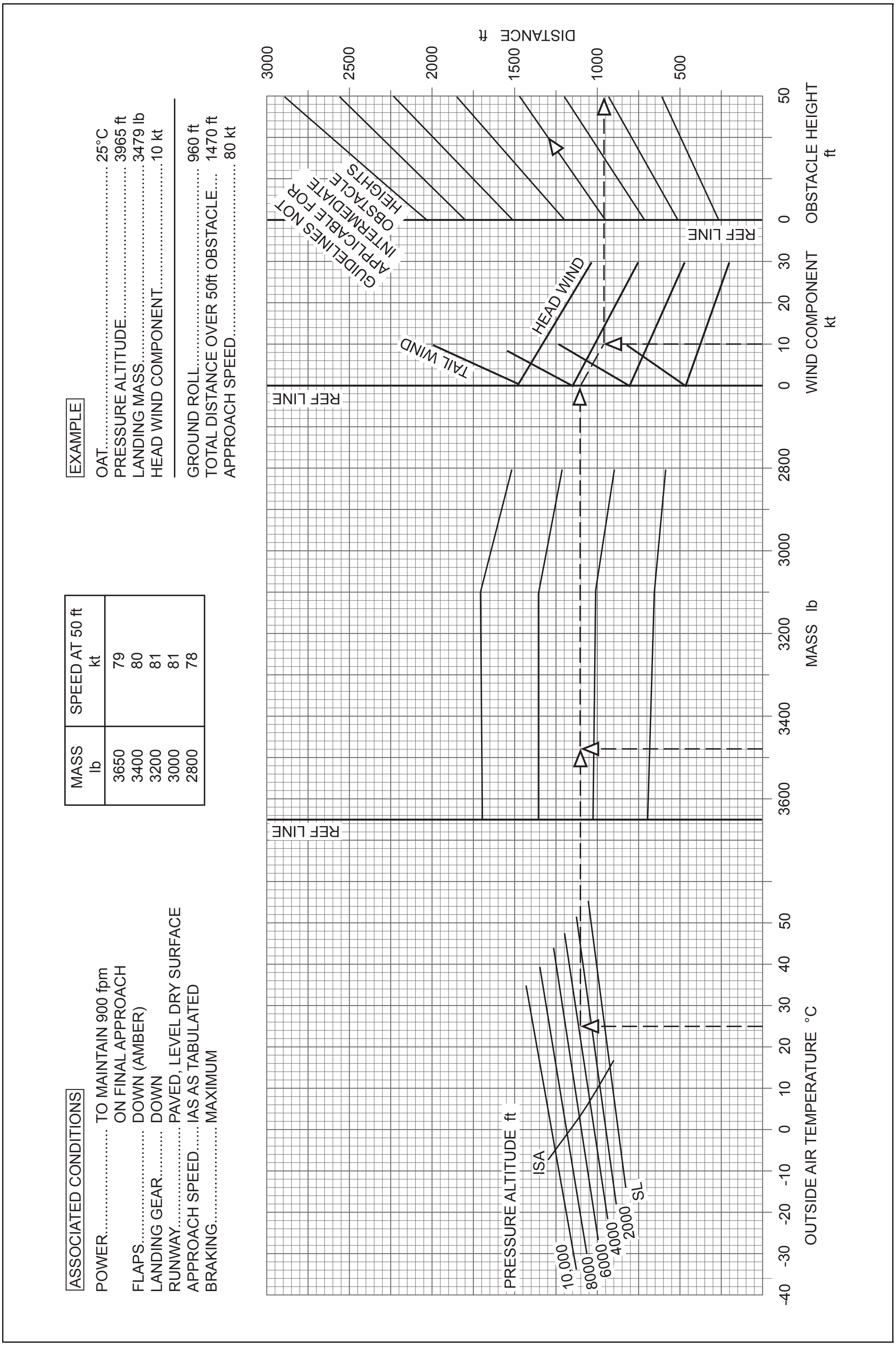

Figure 2.4 Landing

Section 3 Data for Multi-Engine Piston Aeroplane (MEP1)

1 General Considerations

1.1 Performance Classification

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 certificated under CS/FAR 25, is a land-plane and is classified in Performance Class B.

1.2 General Requirements

This class of aeroplane includes all propeller-driven aeroplanes having 9 or less passenger seats and a maximum take-off weight of 5,700 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

1.3 Aeroplane Limitations

Structural Limitations
Maximum Take-Off Mass 4750 lb
Maximum Landing Mass 4513 lb

Runway Crosswind Limitation
Maximum Demonstrated Crosswind 17 kt

2 Take-Off

2.1 Requirements

There are two requirements for take-off with which compliance is necessary. They are the minimum field length and climb gradient requirements. The take-off climb requirements are considered in paragraph 3.

2.1.1 Field Length Requirements

a) When no stopway or clearway is available the take-off distance when multiplied by 1.25 must not exceed TORA.

b) When a stopway and/or clearway is available the take-off distance must:

i) not exceed TORA

ii) when multiplied by 1.3, not exceed ASDA

iii) when multiplied by 1.15, not exceed TODA

c) If the runway surface is other than dry and paved the following factors must be used when determining the take-off distance in a) or b) above:

Surface Type	Condition	Factor
Grass (on firm soil) up to 20 cm. Long	Dry	x 1.2
	Wet	x 1.3
Paved	Wet	x 1.0

d) Take-off distance should be increased by 5% for each 1% upslope. No factorisation is permitted for downslope.

NOTE: The same surface and slope correction factors should be used when calculating TOR or ASD.

2.2 Use of Take-Off Graphs

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.

2.2.1 Distance Calculation

Procedure

To determine the distance used for take-off:

a) Select the appropriate graph.

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

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

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 or ASD as appropriate to the graph used.

ii) For take-off distance continue to the ground roll reference line then parallel the grid lines on Figure 3.1 or Figure 3.3, as appropriate.

f) Factorise for surface and slope.

Example:

Normal Take-Off	
Aerodrome Pressure Altitude	2000 ft
Ambient Temperature	+21°C
Take-Off Mass	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 1,650 ft

Surface Factor = x 1.3
Slope Factor = x 1.075
Take-Off Distance = 2306 ft
Regulatory Factor = x 1.15
Take-Off Distance Required = 2652 ft

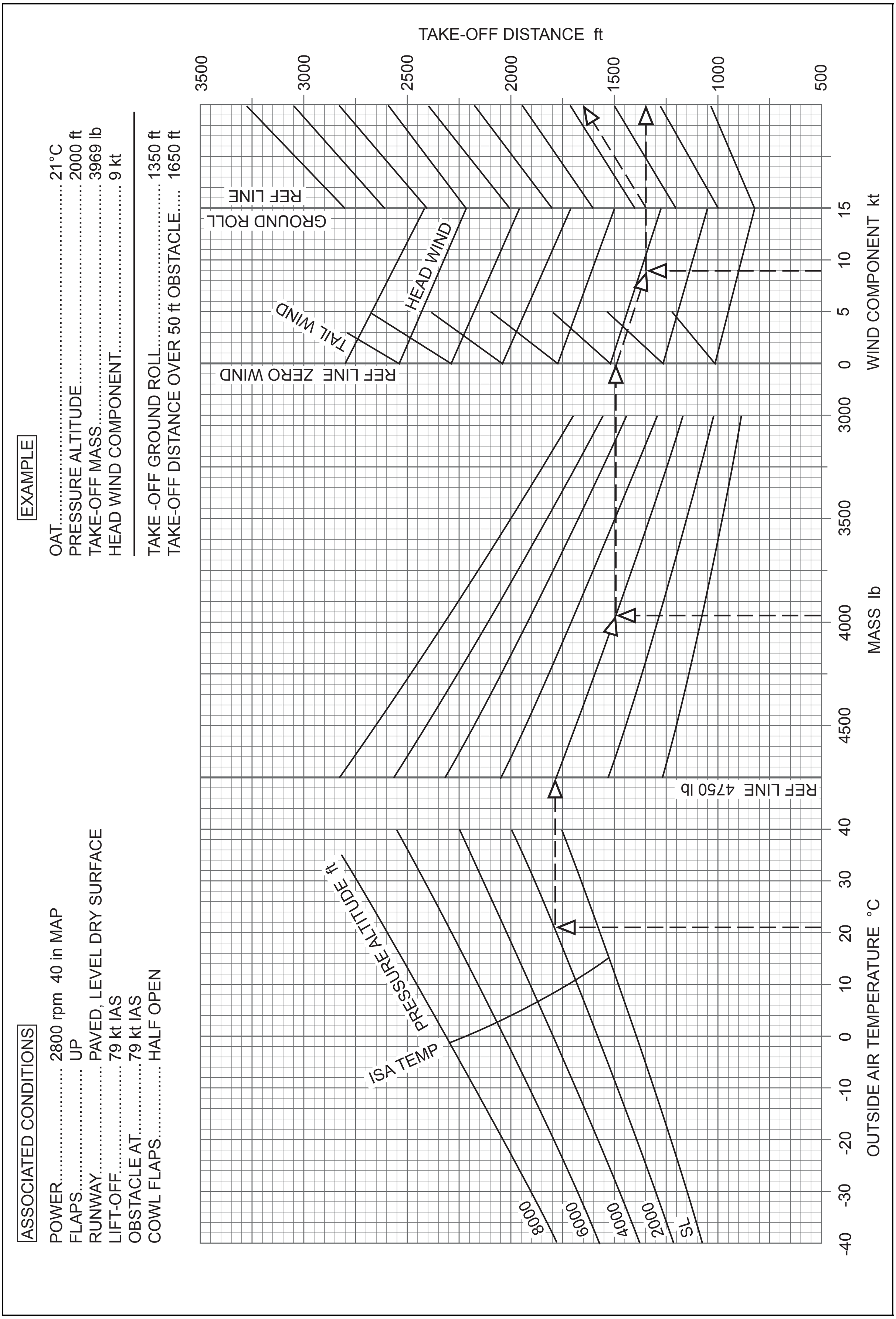

Figure 3.1 Take-Off – Normal Procedure

2.2.2 Mass Calculation

To calculate the field length limited take-off mass 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. Examples are shown at page 6.

Procedure

a) Enter at the ambient temperature. Move vertically to the aerodrome pressure altitude.

b) From this point, travel horizontally right to the mass reference line. Mark this position with a pencil.

c) Enter the right vertical axis at the shortest available de-factored distance at the 50ft height. Parallel the grid lines to the ground roll reference line.

d) Now travel horizontally left to the appropriate wind component input. Parallel the grid lines to the wind component reference line.

e) From this point draw a horizontal line left through the mass grid.

f) From the position marked in b) above, parallel the grid lines to intersect the horizontal line from e) above.

g) At the intersection, drop vertically to read the field length limited TOM.

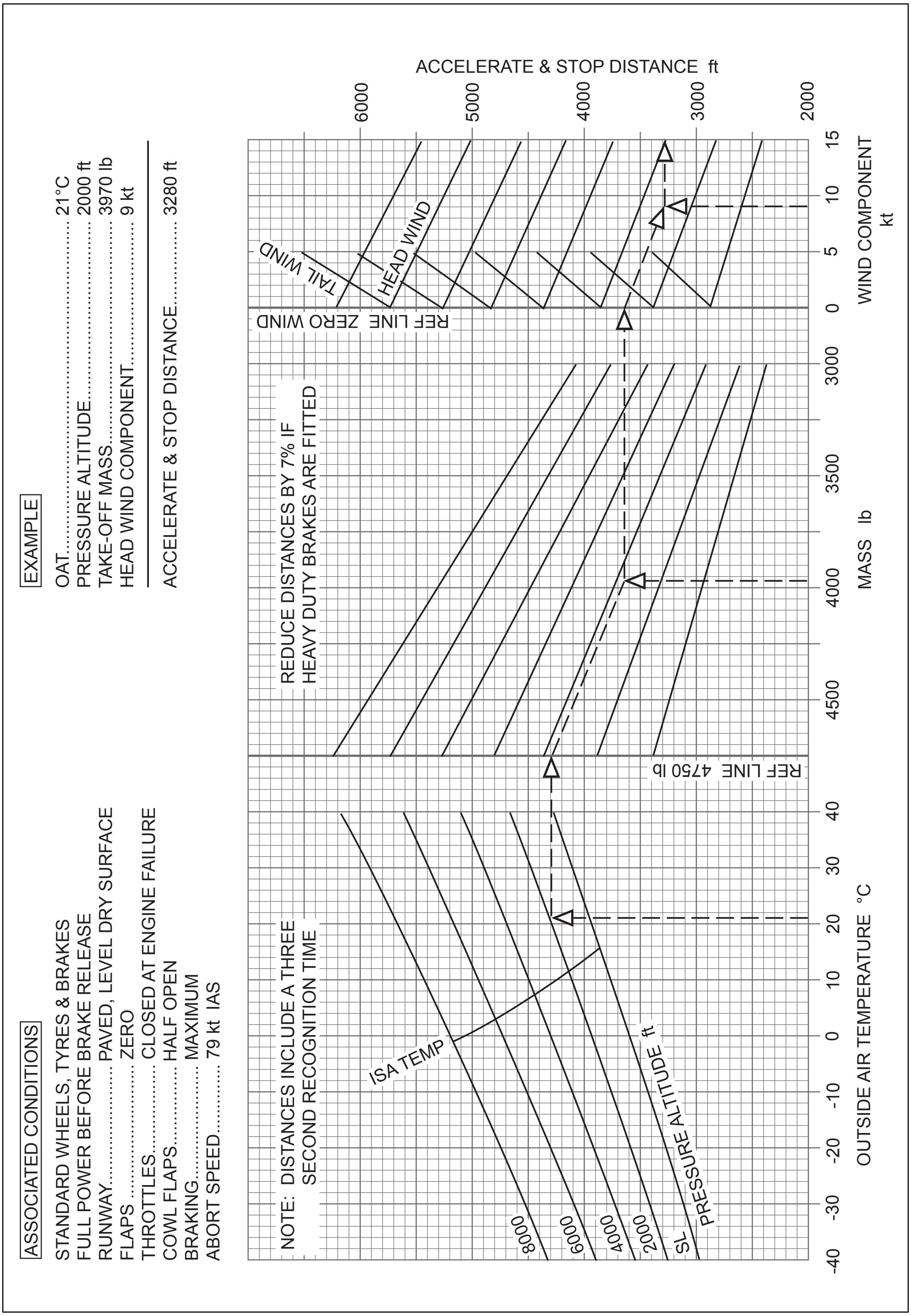

Figure 3.2 Accelerate/Stop Distance – Flaps 0°

Example 1: Maximum Effort Take-Off (Short Field) (Figure 3.3)

Normal Take-Off

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: 2,400 ft; ASDA: 2,500 ft; TODA: 2,600 ft

Calculate the field length limited take-off mass

Solution:

	TORA	**ASDA**	**TODA**
Given Distances	2400 ft	2500 ft	2600 ft
Slope Factor	1.1	1.1	1.1
Surface/Condition Factor	1.2	1.2	1.2
Regulation Factor	1.0	1.3	1.15
De-Factored Distance	1818 ft	1457 ft	1713 ft

Field Length Limited TOM 4000 lb, Using 1457 ft

Example 2: Normal Take-Off (Figure 3.1)

Aerodrome Pressure Altitude	4000 ft
Ambient Temperature	+20°C
Wind Component	5 kt Tail
Runway Slope	2% down
Surface Type	Concrete
Surface Condition	Wet
TORA: 2500 ft	No Stopway or Clearway

Calculate the field length limited take-off mass

Solution:

Given Distance	2500 ft
Slope Factor	÷1.0
Surface Condition Factor	÷1.0
Regulation Factor	÷1.25
De-factored Distance	2000 ft
Field Length Limited TOM	3100 lb Using 2000 ft

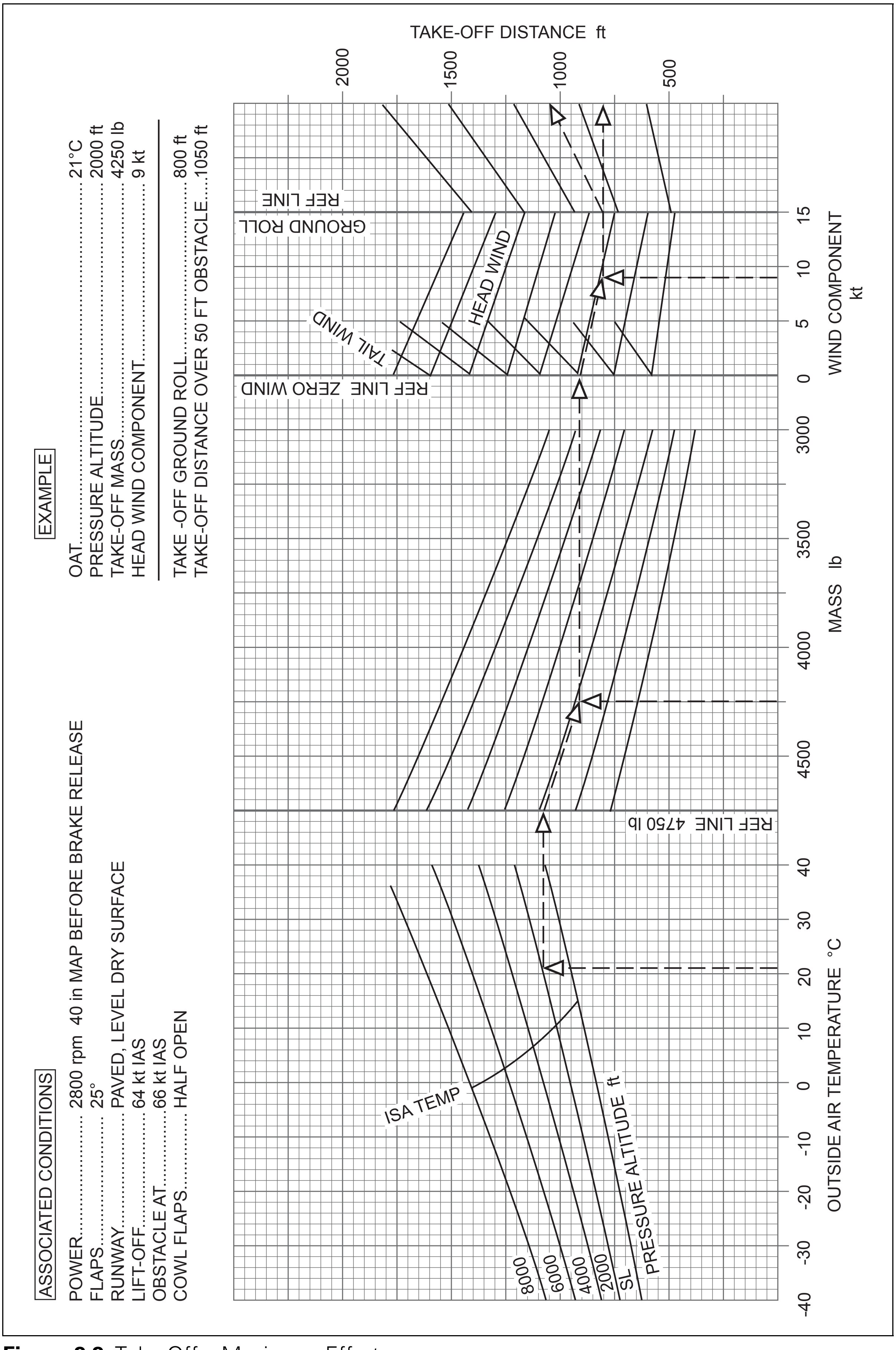

Figure 3.3 Take-Off – Maximum Effort

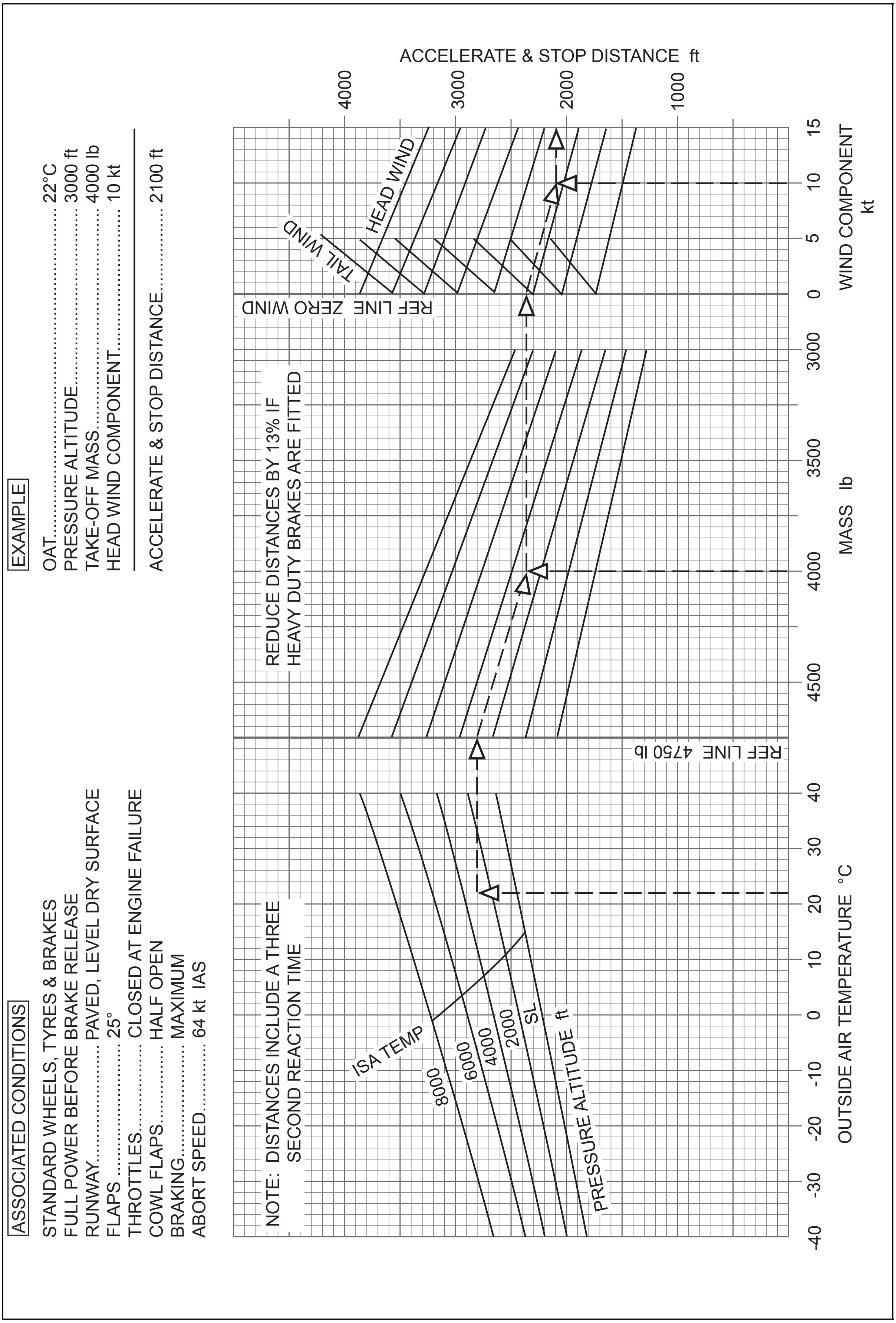

Figure 3.4 Accelerate/Stop Distance – Flaps 25°

3 Take-Off Climb

3.1 Requirements

The take-off climb requirements only apply to aeroplanes with two or more engines. The take-off climb extends from 50 ft above the surface at the end of TODR to 1500 ft above the same surface. The maximum take-off power setting is limited to 5 minutes from the commencement of the take-off climb, at which point it must be reduced to the maximum continuous power setting.

If visual reference for obstacle avoidance is lost, it is assumed that the critical power unit becomes inoperative at this point. All obstacles encountered in the accountability area must be cleared by a vertical interval of 50 ft

Turns are not permitted in the take-off climb before the end of the TODR and thereafter the angle of bank must not exceed 15°.

3.1.1 The Obstacle Accountability Area

The dimensions of the obstacle accountability area are as follows:

a) Starting semi-width at the end of TODA of 90 m, if the wing span is less than 60 m, then (60 m + ½ wing span) is the semi-width to be used.

b) The area expands from the appropriate semi-width, at the rate of 0.125 x D, to the maximum semi-width where D is the horizontal distance travelled from the end of TODA or TOD if a turn is scheduled before the end of TODA.

c) Maximum Semi-width

Condition	**Maximum Semi-width**	
Change of Track Direction	**0° to 15°**	**Over 15°**
Able to Maintain Visual Guidance or same Accuracy	300m.	600 m.
All Other Conditions	600 m	900 m.

3.1.2 Minimum Gradients of Climb

The minimum permissible gradients of climb, as specified in JAR-OPS 1, are:

a) All engines operating … 4% at screen height

b) One engine inoperative:

i) at 400 ft above the take-off surface level … measurably positive.

ii) at 1500 ft above the take-off surface level … 0.75%.

3.2 Use of Take-Off Climb Data

Because the graphs provided only permit the calculation of the rate of climb it is necessary to utilise the following formula to solve take-off climb problems:

$$\text{Time to Climb} = \frac{\text{Height Difference (ft)}}{\text{Rate of Climb (fpm)}} \times 60 \text{ seconds}$$

$$\text{Distance to Climb nm} = \frac{\text{Height Difference (ft)}}{\text{Rate of Climb (fpm)}} \times \frac{\text{Groundspeed (kt)}}{60}$$

$$\text{Still Air Gradient of Climb} = \frac{\text{Rate of Climb (fpm)}}{\text{TAS (kt)}} \times \frac{6000}{6080}\%$$

3.2.1 Climb graphs

There are three graphs provided for climb calculations:

a) Gear extended, maximum take-off power (Figure 3.5)

b) Gear retracted, maximum take-off power (Figure. 3.6)

c) Gear retracted, maximum continuous power (Figure 3.7)

NOTE: If a graph is used to show compliance with the obstacle clearance requirement, the gradient from 50 ft to the assumed engine failure height is to be the average all-engine gradient x 0.77. This is equivalent to the distance travelled with all engines operating x 1.3.

3.2.2 Use of Graph (Figure 3.5)

a) Enter with the temperature and travel vertically to the pressure altitude.

b) Travel horizontally to the curved graph line.

c) From this intersection drop a vertical line to the bottom scale. Read off rate of climb.

An example is shown on the graph.

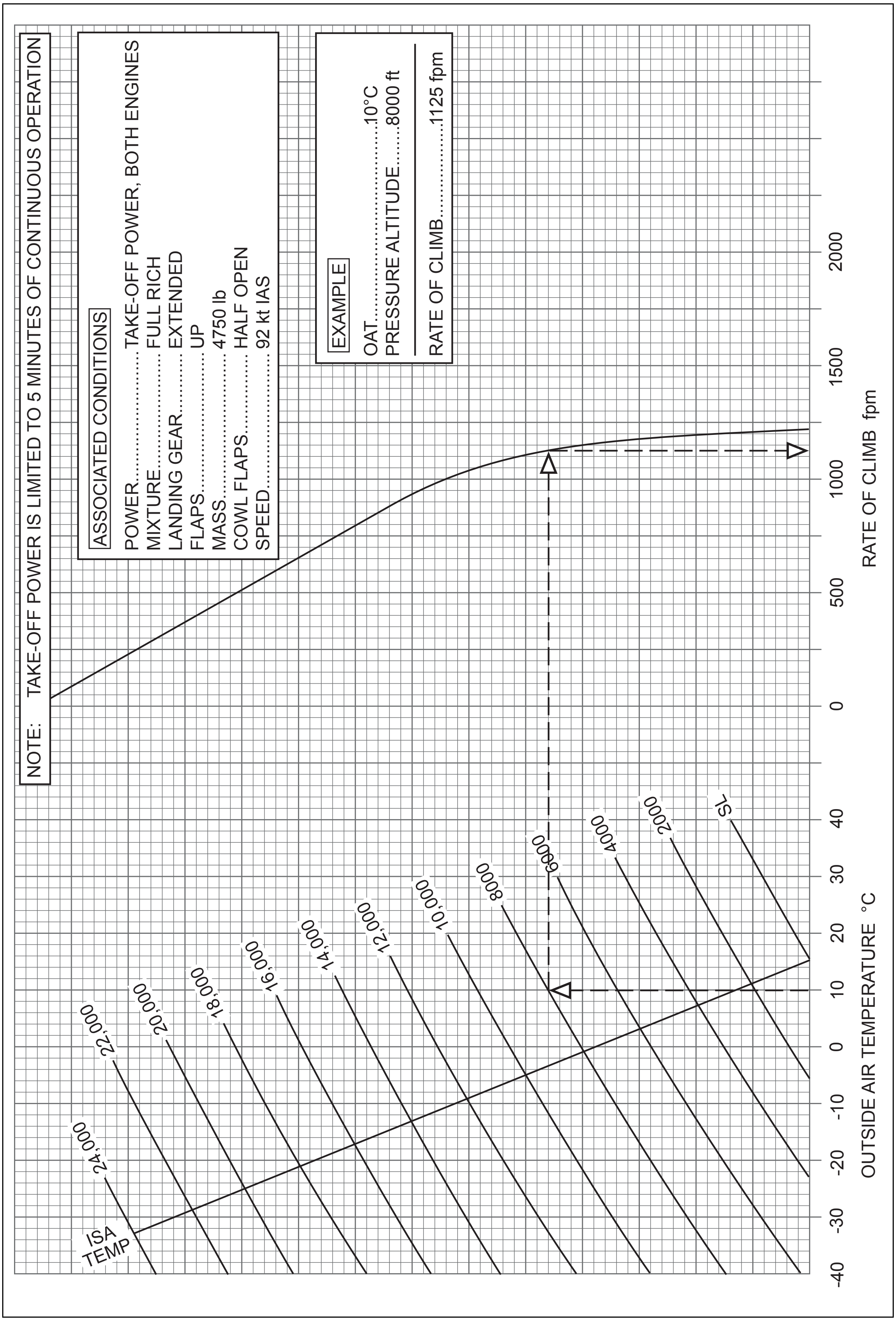

Figure 3.5 Take-Off Climb Performance – Gear Extended

3.2.3 Use of Graphs (Figure 3.6 and Figure 3.7)

a) Enter with OAT. Travel vertically to the pressure altitude.

b) From this point, travel horizontally right to intercept the interpolated value of take-off mass.

c) Drop vertically to read the all-engine-operating rate of climb.

d) From the TOM intersection, continue horizontally right to intercept the second interpolated weight (if applicable).

e) Drop vertically to read the one-engine-inoperative rate of climb.

Example 1:

Aerodrome Pressure Altitude	10000 ft
Ambient Temperature	+10°C
Take-Off Mass	4000 lb
Gear up (Undercarriage Retracted)	
Flaps 0°;	
Climb speed	92 kt IAS
Cloud Base	400 ft above Reference Zero
Wind Component	40 kt Head

Calculate the distance from the end of TODR to 1500 ft above Reference Zero for the purpose of obstacle clearance.

Solution:

All engines rate of climb at take-off power 1650 fpm
One engine inoperative rate of climb at take-off power 300 fpm
One engine inoperative rate of climb at MCP 220 fpm
Time to cloud base at take-off power = $\frac{350}{1650} \times 60 = 12.73$ seconds

Time to 1500 ft from cloud base at take-off power =
$\frac{1100}{300} \times 60 = 220$ seconds = 3 minutes 40 seconds.

Total time = 12.73 Seconds + 3 minutes 40 seconds = 3 minutes 52.73 seconds.
i.e. less than 5 minutes. Therefore Maximum Take-off Power can be maintained throughout the climb.

92 kt IAS = 110 kt TAS.

G/S = 110 = 20 = 90 kt (Using 50% of head wind component)

Distance to cloud base = $\frac{350}{1650} \times \frac{90}{60} \times 1.3 = 0.414$ NM

Distance cloud base to 1500 = $\frac{1100}{300} \times \frac{90}{60} = 5.5$ NM

Total Distance = 0.414 + 5.5 = 5.914 NM

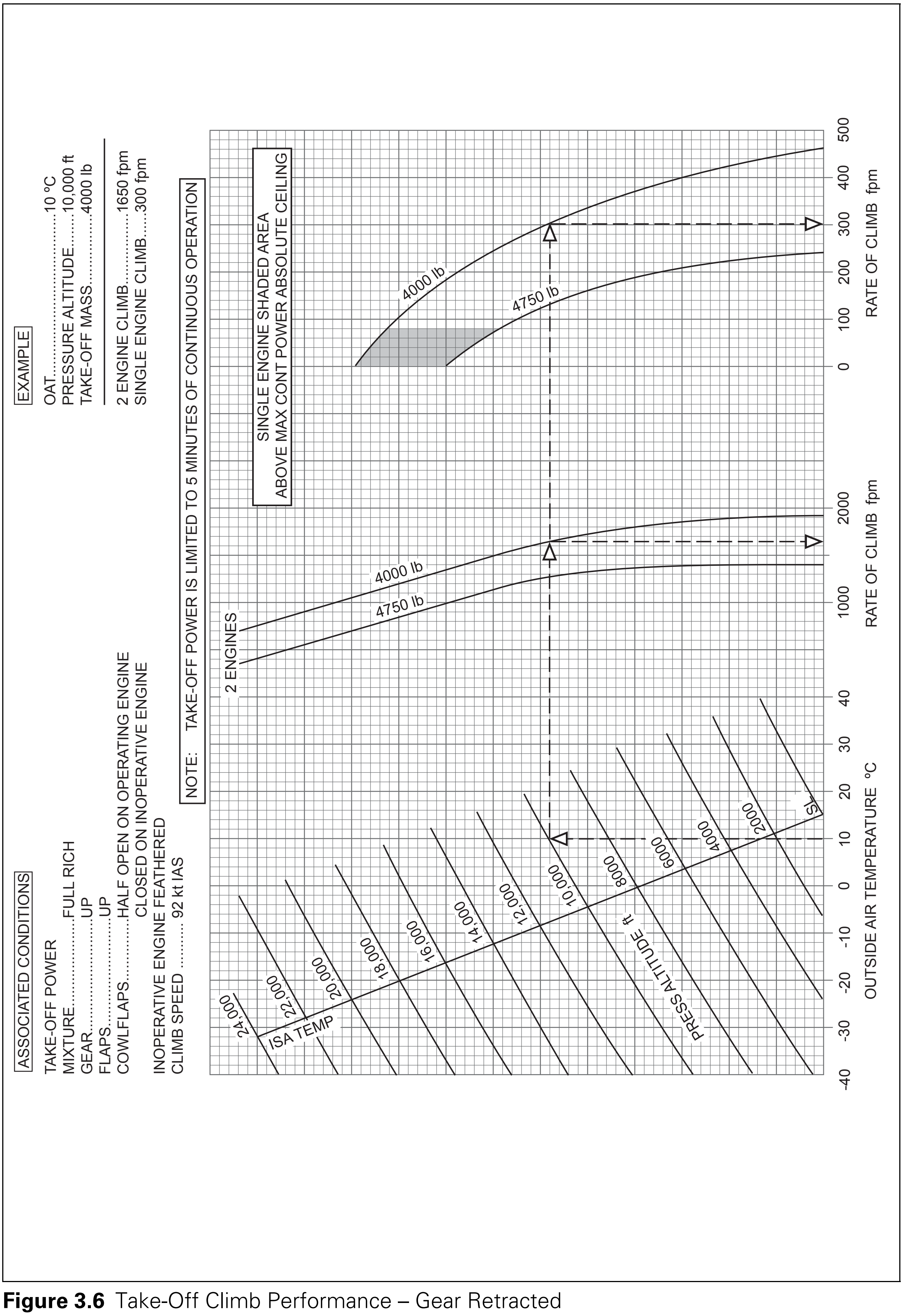

Figure 3.6 Take-Off Climb Performance – Gear Retracted

Example 2:

Aerodrome Pressure Altitude	6000 ft
Ambient Temperature	+20°C
Take-Off Mass	4500 lb
Gear up (Undercarriage Retracted)	
Flaps 0°	
Climb Speed	92 kt IAS
Cloud Base	400 ft above Reference Zero
Wind Component	13 kt Tail

Obstacle in the domain at 14000 ft from the end TODR and 600 ft above Reference Zero

Calculate the vertical clearance of the obstacle by the aeroplane.

Solution:

Figure 3.6 All engines rate of climb at take-off power 1510 fpm
Figure 3.6 One engine inoperative rate of climb at take-off power 255 fpm
Figure 3.7 One engine inoperative rate of climb at maximum continuous power 220 fpm

Time to cloud base $= \frac{350}{1510} \times 60 = 13.9$ seconds

Time to 1500 ft from cloud base =

$\frac{1100}{255} \times 60 = 258.8$ seconds = 4 minutes 18.8 seconds

Total time = 13.9 seconds + 4 minutes 18.8 seconds = 4 minutes 32.7 seconds. Therefore Maximum Take-Off power can be maintained throughout the take-off climb.

92 kt IAS = 104 kt TAS.

G/S = 104 + 20 = 124 kt (Using 150% of tailwind component rounded up)

Distance to cloud base $= \frac{350}{1510} \times \frac{124}{60} \times 6080 \times 1.3 = 3786$ ft

Distance cloud base to obstacle = 14000 - 3786 = 10214 ft

Height gain $= \frac{10214 \times 255 \times 60}{124 \times 6080} = 207.3$ ft

Height at obstacle = 400 + 207.3 = 607.3 ft

Clearance = 607.3 - 600 = 7.3 ft

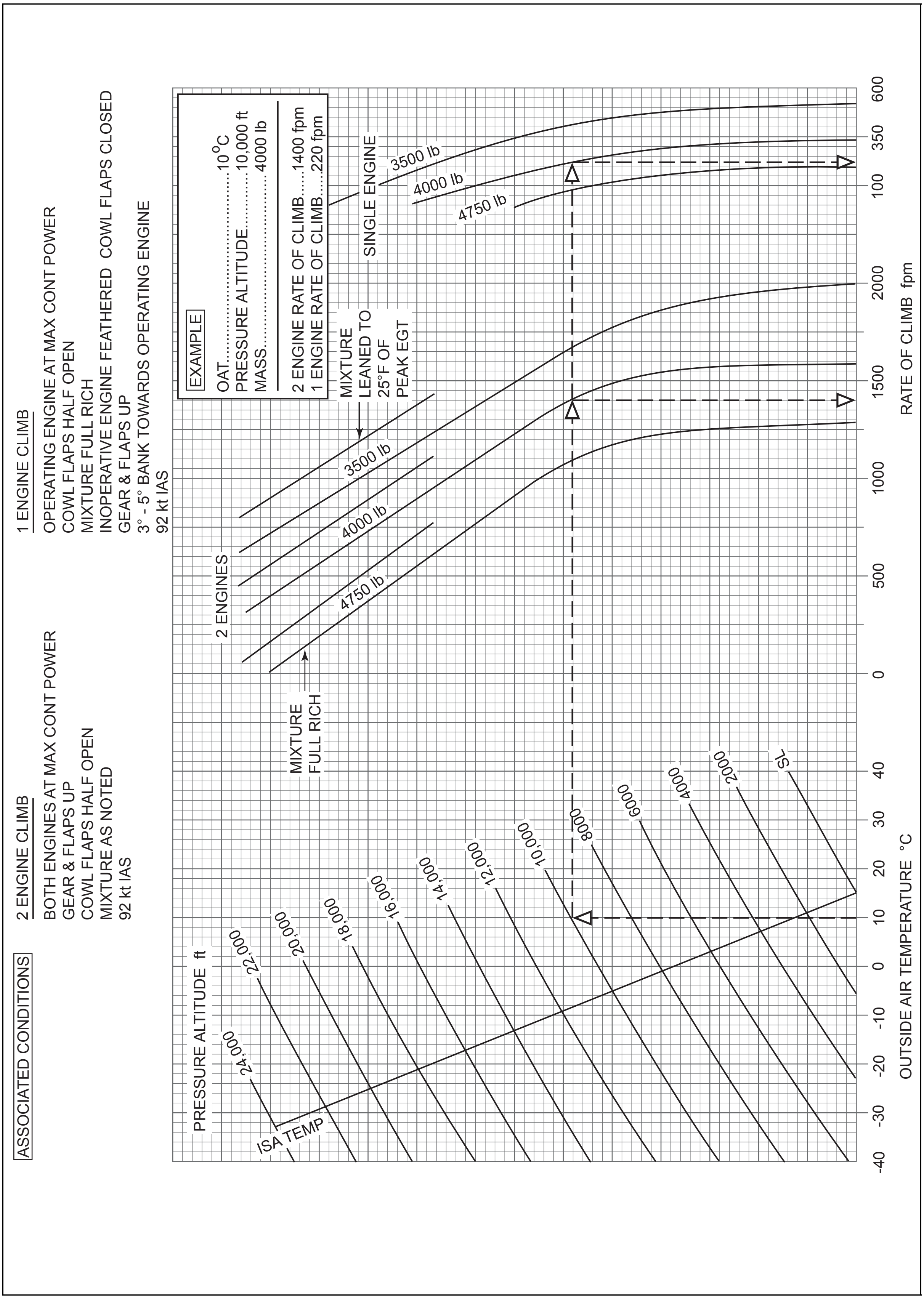

Figure 3.7 Climb Performance – Gear Retracted Maximum Continuous Power

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4 En-route

The en-route phase extends from 1500 ft above the take-off surface level to 1000 ft above the landing aerodrome surface level.

4.1 Requirements

In the event of engine failure, with the remaining engine(s) set at the maximum continuous setting, the aeroplane must be able to continue flight at or above the relevant minimum safe altitude to an aerodrome at which the landing requirements can be attained.

To show compliance:

a) The aeroplane may not be assumed to be flying above that altitude at which the rate of climb is 300 fpm with all engines operating.

b) The one-engine-inoperative net gradient of climb is the gross gradient of climb decreased by 0.5%, or the net gradient of descent is the gross gradient of descent increased by 0.5%.

5 Landing

5.1 Requirements

There are three requirements for landing with which compliance is necessary. They are the climb gradient requirements in the event of a balked landing and a missed approach, and the landing field length requirement.

5.1.1 Field Length Requirements

a) The landing distance, from a screen height of 50 ft, must not exceed 70% of the landing distance available, i.e. a factor of 1.43.

b) If the landing surface is grass up to 20 cm long on firm soil, the landing distance should be multiplied by a factor of 1.15.

c) If the METAR or TAF or combination of both indicate that the runway may be wet at the estimated time of arrival, the landing distance should be multiplied by a factor of 1.15.

d) The landing distance should be increased by 5% for each 1% downslope. No allowance is permitted for upslope.

e) The despatch rules for scheduled (planned) landing calculations are in JAR-OPS 1.550 (c).

5.1.2 Balked Landing Requirements

The minimum acceptable gross gradient of climb after a balked landing is 2.5%. This must be achieved with:

a) The power developed 8 seconds after moving the power controls to the take-off position.

b) The landing gear (undercarriage) extended.

c) Flaps at the landing setting.

d) Climb speed equal to V_{REF}.

5.1.3 Missed Approach Requirements

The minimum acceptable gross gradient of climb, after a missed approach, is 0.75% at 1500 ft above the landing surface. This must be achieved with:

a) The critical engine inoperative and the propeller feathered.

b) The live engine set at maximum continuous power.

c) The landing gear (undercarriage) retracted.

d) The flaps retracted.

e) Climb speed not less than 1.2 V_{S1}.

Example: Flaps Up

Aerodrome Pressure Altitude	=	6000 ft
Ambient Temperature	=	+10°C
Aeroplane Mass	=	4000 lb

Calculate the missed approach gradient of climb:

Solution: Use Figure 3.7: One-engine-inoperative grid

True Airspeed	=	102 kt
Rate of Climb	=	300fpm
Gradient of Climb	=	$\frac{300}{102} \times \frac{6000}{6080} = 2.9\%$

5.2 Balked Landing Climb Graph

The graph provided for this purpose is constructed for the maximum landing mass of 4513 lb (Figure 3.8).

Use of Graph:

a) Enter at the ambient temperature. Travel vertically to the aerodrome pressure altitude.

b) From this point travel horizontally right to intercept the rate of climb graph line. Now drop a vertical to read the rate of climb.

c) Convert the rate of climb to a still-air gradient of climb using the formula:

$$\text{Still Air Gradient of Climb} = \frac{\text{ROC (fpm)}}{\text{TAS (kt)}} \times \frac{6000}{6080}\ \%$$

Example:

Aerodrome Pressure Altitude	3000 ft
Ambient Temperature	+22°C

Solution:

Graphical ROC	=	810 fpm.
IAS 85 kt	=	91 kt TAS
Climb Gradient	=	$\frac{810}{91} \times \frac{6000}{6080} = 8.78\%$

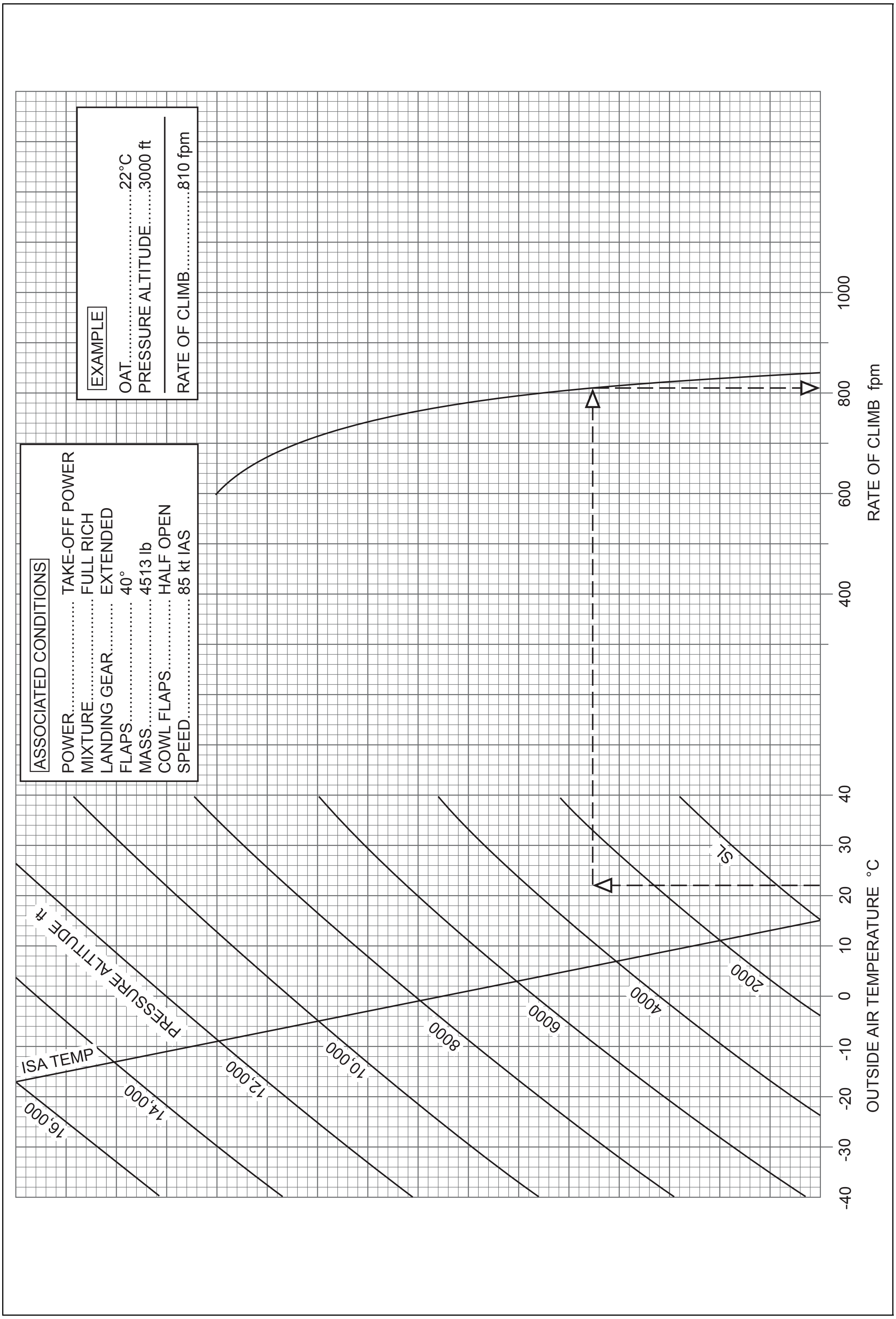

Figure 3.8 Balked Landing Climb Performance

5.3 Use of Landing Field Length Graphs

There are two landing field length graphs: one for normal landings with 40° landing flap (Figure 3.9), and the other for short field landings with 40° landing flap. (Figure 3.10).

5.3.1 Distance Calculations

a) Enter at the ambient temperature. Move vertically to the aerodrome pressure altitude.

b) From this point, move horizontally right to the landing weight reference line. Parallel the grid lines to the appropriate landing mass input.

c) Continue from this intersection to the wind component reference line. Parallel the grid lines to the appropriate wind component input.

d) Travel horizontally right to the ground roll reference line. Either continue horizontally to the right vertical axis to read the ground roll distance or parallel the grid lines to the right vertical axis to read the landing distance from 50 ft.

e) Apply the appropriate factors to the landing distance to obtain the landing distance required.

Example: Normal Landing

Aerodrome Pressure Altitude	3000 ft
Ambient Temperature	+22°C
Landing Mass	3650 lb
Wind Component	10 kt Head
Runway Slope	1% Down
Runway Surface	Grass
Runway Condition	Wet

Calculate Landing Distance Required

Solution:

Graphical Distance	2220 ft
Slope Correction Factor	x 1.05
Surface Correction Factor	x 1.15
Condition Correction Factor	x 1.15
Regulatory Factor	x 1.43
Landing Distance Required	= 4408ft

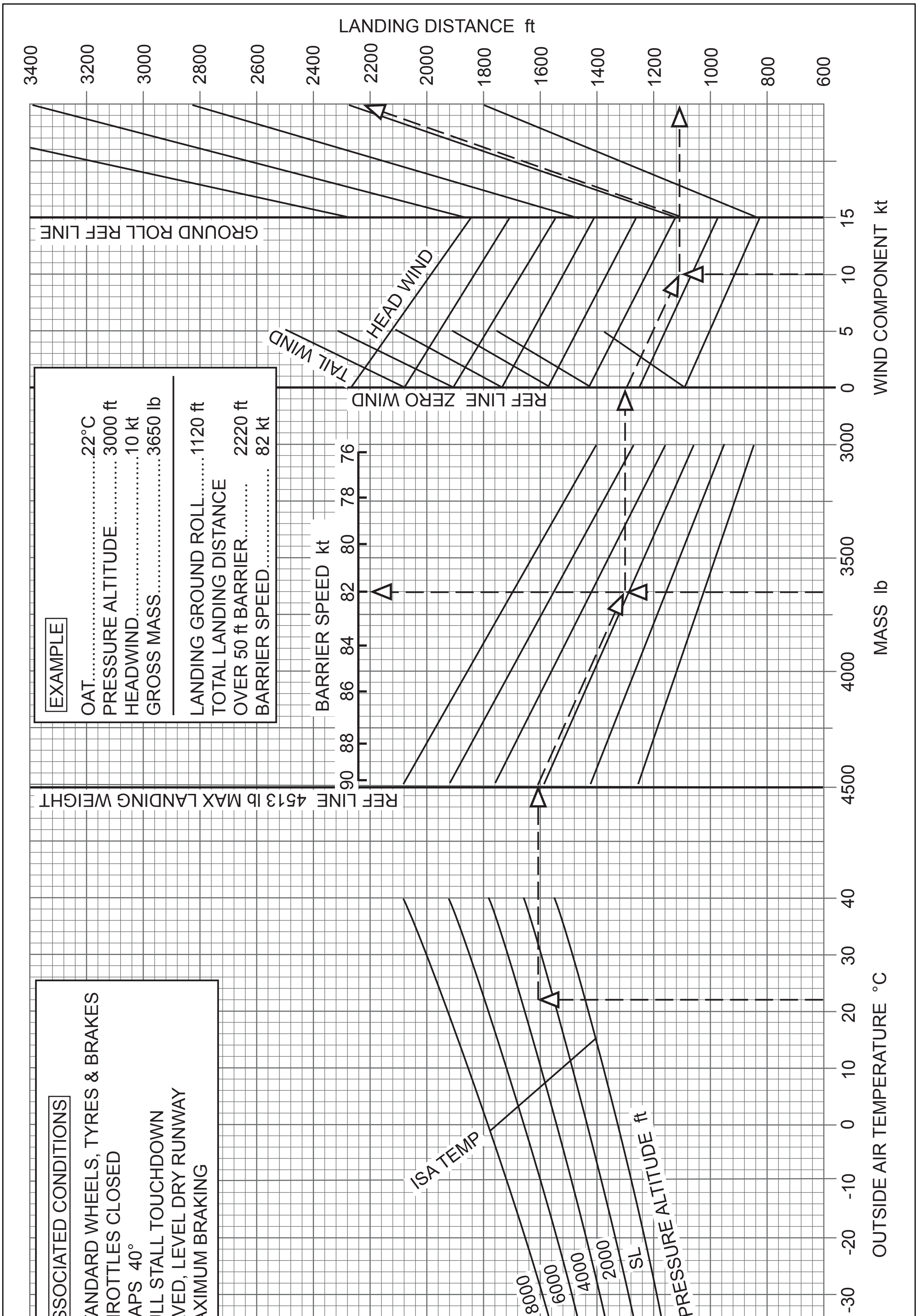

Figure 3.9 Landing Distance Normal Procedure

5.3.2 Landing Mass Calculations

The procedure for calculating the field length limited landing mass is:

a) De-factorise the landing distance available by dividing by the slope correction factor, the surface type correction factor, the surface condition correction factor and the regulatory factor.

b) Enter at the ambient temperature. Move vertically to the aerodrome pressure altitude.

c) From this point, travel horizontally right to the mass reference line. Mark with a pencil.

d) Enter right vertical axis with the distance from a) above. Parallel the grid lines to the ground roll reference line.

e) From this point, travel horizontally left to the appropriate wind component input. Parallel the grid lines to the wind component reference line.

f) Now draw a line horizontally from this point through the mass grid.

g) From the pencil mark in c) above, parallel the grid lines to intersect the horizontal line. Drop vertically to read field length limited landing mass.

Example: Short Field Landing

Aerodrome Pressure Altitude	3000 ft
Ambient Temperature	+22°C
Landing Distance Available	3733 ft
Wind Component	10 kt Head
Runway Slope	1% down
Runway Surface	Grass
Runway Condition	Wet

Calculate the field length limited landing mass

Solution:

Landing Distance Available	3733 ft
Slope Correction Factor	÷1.05
Surface Type Correction Factor	÷1.15
Surface Condition Correction Factor	÷1.15
Regulatory Factor	÷1.43
De-factorised LDA	= 1880 ft
Field Length Limited Landing Mass	= 3800 lb

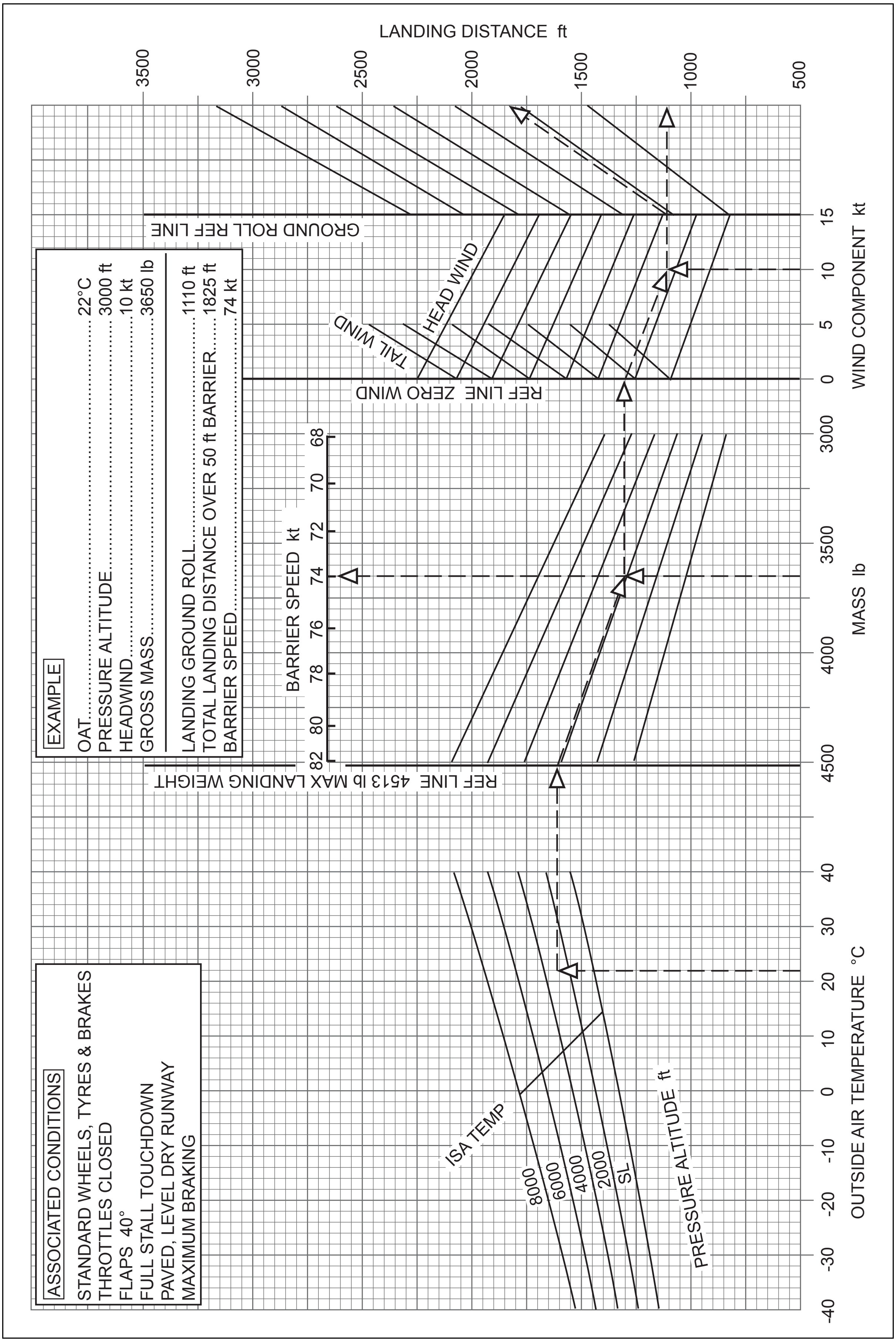

Figure 3.10 Landing Distance Short Field

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Section 4 Data for Medium-Range Jet Transport (MRJT1)

1 General Considerations

1.1 Performance Limitations

1.1.1 Performance Classification

The specimen aircraft is a landplane powered by two turbo fan engines. It is certificated in the Transport Category (Passenger) and is operated in accordance with CS/FAR 25 Performance Class A.

1.1.2 Flight Over Water Speed

The true airspeed to be assumed for the purpose of compliance with legislation governing flight over water and en-route climb performance is 380 knots.

1.1.3 Engine Relighting

The maximum altitude to be assumed for engine relighting is 25000 feet.

1.1.4 Maximum Crosswind Component

The maximum crosswind component in which the aeroplane has been demonstrated to be satisfactory for take-off and landing is 33 knots. This wind speed is related to a height of 10 metres.

1.1.5 Standard Performance Conditions

Performance information relates to an average aeroplane of the type and the data are based on:

a) Certified engine thrust ratings less installation losses, airbleed and accessory losses.

b) Full temperature accountability within operational limits except for landing distance, which is based on standard day temperatures.

c) Trailing edge flap settings:

- 5° or 15° for take-off,
- 4° transition setting,
- 22° for approach,
- 15°, 30°, 40° for landing

with leading edge devices in the full down position for these flap settings.

d) Operations on smooth, hard-surfaced, runways.

1.2 Aeroplane Limitations

1.2.1 Mass (Weight)

Maximum structural take-off mass is 62800 kg.
Maximum structural landing mass is 54900 kg.
Maximum zero fuel mass is 51300 kg.
On any given occasion, the maximum permitted take-off and landing mass may be less than the structural limits given above.

1.2.2 **Wing Span**

The wingspan of the aeroplane is 28.88 metres.

1.2.3 **Power Plant**

The engines shall not be operated continuously at maximum take-off thrust for periods exceeding 5 minutes.

1.2.4 **Operating Limitations**

Operational mass (weight) limits are determined from the following performance considerations:

a) Take-off field lengths.

b) Take-off climb limits.

c) Tyre speed limits.

d) Brake energy limits.

e) Net take-off flight path.

f) En route climb performance.

g) Landing climb limits.

h) Landing field lengths.

1.3 **Additional Definitions for Class 'A' Aeroplanes**

Air Minimum Control Speed - V_{MC}	The minimum flight speed at which the aeroplane is controllable, with a maximum of 5° bank, when the critical engine suddenly becomes inoperative with the remaining engines at take-off thrust.
Approach and Landing Minimum Control Speed - V_{MCL}	The minimum speed with a wing engine inoperative where it is possible to decrease thrust to idle or increase thrust to maximum take-off without encountering dangerous flight characteristics.
Decision Speed - V_1	The maximum speed during take-off at which the pilot must take the first action (e.g. apply brakes, reduce thrust, deploy speed brakes) to stop the aeroplane within the accelerate-stop distance available. It is also the minimum speed during take-off, following the failure of the critical engine at $V_{EF,}$ at which the pilot can continue the take-off and achieve screen height within the take-off distance available. V_1 must not be less than V_{MCG}, not greater than V_R and not greater than V_{MBE}.
Ground Minimum Control Speed - V_{MCG}	The minimum speed on the ground at which the take-off can be safely continued, when the critical engine suddenly becomes inoperative with the remaining engines at take-off thrust.

Maximum Brake Energy Speed - V_{MBE}	The maximum speed on the ground from which an aeroplane can safely stop within the energy capabilities of the brakes.
Maximum Threshold Speed - V_{TMAX}	The speed at the threshold above which the risk of exceeding the scheduled landing field length is unacceptably high. Go-around action should normally be taken if it appears that maximum threshold speed will be exceeded. This speed is 15 knots greater than the all-engines operating target threshold speed.
PMC	Power Management Computer.
QRH	Quick Reference Handbook.
Reference Landing Speed - V_{REF}	The speed of the aeroplane, in the specified landing configuration, at screen height, which is used to determine the landing distance for manual landings.
Rotation Speed - V_R	The speed at which, during the take-off, rotation is initiated with the intention of becoming airborne.
Screen Height	The height of an imaginary screen placed at the end of the Take-Off Distance Required and at the beginning of the Landing Distance Required.
Steady Initial Climb Speed - V_4	The all engines operating take-off climb speed used to the point where acceleration to flap retraction speed is initiated. V_4 should be attained by a gross height of 400 feet.
Take-Off Safety Speed - V_2	The target speed to be attained at the screen height with one engine inoperative, and used to the point where acceleration to flap retraction speed is initiated.
Threshold Speed - V_T	The speed at which the pilot should aim to cross the runway threshold to ensure that the scheduled landing field lengths are consistently achieved. The speeds at the threshold are: V_{TO} - all engines operating V_{T1} - a critical engine inoperative

1.4 **The Determination of Wind Component**

Use the graph at Figure 4.1

a) Calculate the relative direction of the wind to the runway. i.e. (wind direction - runway direction) or (runway direction - wind direction).

b) Enter graph at left vertical axis with windspeed.

c) Follow circle until relative direction intercepted.

d) From the intersection draw a line horizontally left to the vertical axis to read the along track component. Negative values are tailwinds.

e) From the intersection drop a vertical line to intersect the horizontal axis to read the crosswind component.

f) The windspeed grids have already been factorised 50% for headwinds and 150% for tailwinds. Therefore the grids may be entered with the reported or calculated along track component.

Example: W/V 330/30 Runway 02

Wind angle = 50°
Headwind = 19 kt Crosswind = 23 kt left to right.

Note this graph is for use with take-off and landing computations only.

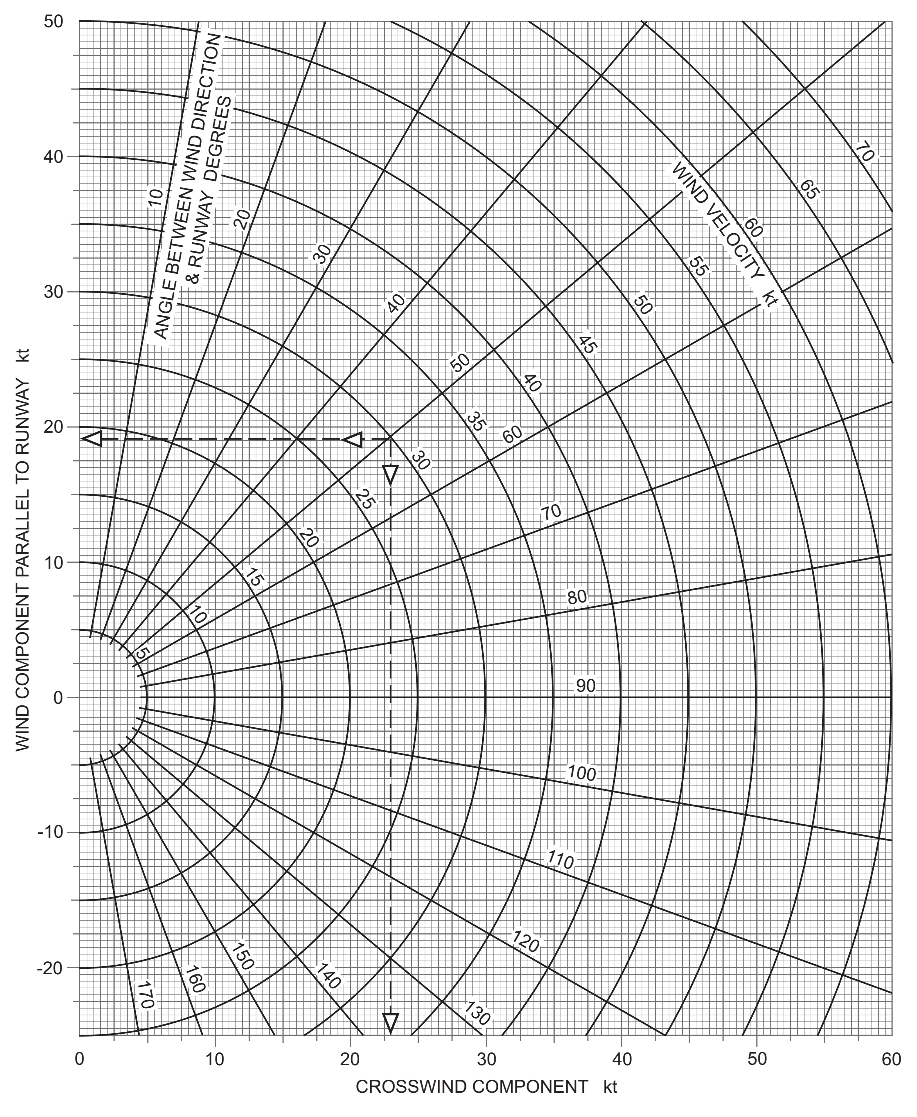


Figure 4.1 Wind Components for Take-Off and Landing

1.5 Conversion of QFE or QNH to Pressure Altitude

All altitudes in this manual refer strictly to pressure altitude. If only QFE or QNH are known then it must be used to produce a pressure altitude.

QNH (IN.HG.)			Correction to elevation for press. Alt. (ft)	QNH (hPa)		
28.81	to	28.91	+1000	976	to	979
28.91	to	29.02	+900	979	to	983
29.02	to	29.12	+800	983	to	986
29.12	to	29.23	+700	986	to	990
29.23	to	29.34	+600	990	to	994
29.34	to	29.44	+500	994	to	997
29.44	to	29.55	+400	997	to	1001
29.55	to	29.66	+300	1001	to	1004
29.66	to	29.76	+200	1004	to	1008
29.76	to	29.87	+100	1008	to	1012
29.87	to	29.97	0	1012	to	1015
29.97	to	30.08	-100	1015	to	1019
30.08	to	30.19	-200	1019	to	1022
30.19	to	30.30	-300	1022	to	1026
30.30	to	30.41	-400	1026	to	1030
30.41	to	30.52	-500	1030	to	1034
30.52	to	30.63	-600	1034	to	1037
30.63	to	30.74	-700	1037	to	1041
30.74	to	30.85	-800	1041	to	1045
30.85	to	30.96	-900	1045	to	1048
30.96	to	31.07	-1000	1048	to	1052

Figure 4.2 QNH To Pressure Altitude

Example:		
	Elevation	= 2500 ft
	QNH	= 29.48 in.Hg.
	Correction	= +400 ft
	Press Alt.	= 2900 ft

1.6 Total Air Temperature at ISA

The cockpit temperature gauge shows the total air temperature (TAT), which is the true outside air temperature plus the rise due to ram air compression. To calculate the value of TAT, while flying in ISA conditions, enter the table in figure 4.3 at the appropriate pressure altitude and move along the line to the appropriate indicated Mach number to read the ISA/TAT.

Compare the actual TAT with the tabulated ISA/TAT to obtain the temperature deviation from standard.

Pressure Altitude 1000 ft	**Indicated Mach Number**													
	0	**.40**	**.50**	**.60**	**.70**	**.74**	**.78**	**.80**	**.82**	**.84**	**.86**	**.88**	**.90**	**.92**
36 to 45	-56			-41	-35	-33	-30	-29	-27	-26	-24	-23	-21	-20
35	-54			-39	-33	-30	-28	-26	-25	-23	-22	-20	-19	-17
34	-52		-41	-36	-31	-28	-25	-24	-23	-21	-20	-18	-17	-15
33	-50		-39	-34	-29	-26	-23	-22	-20	-19	-17	-16	-14	-13
32	-48		-37	-32	-26	-24	-21	-20	-18	-17	-15	-14	-12	-10
31	-46		-35	-30	-24	-22	-19	-17	-16	-14	-13	-11	-10	-8
30	-44		-33	-28	-22	-19	-17	-15	-14	-12	-11	-9	-7	-6
29	-42		-31	-26	-20	-17	-14	-13	-11	-10	-8	-7	-5	-3
28	-40		-29	-24	-18	-15	-12	-11	-9	-8	-6	-4	-3	-1
27	-38		-27	-22	-15	-13	-10	-8	-7	-5	-4	-2	0	1
26	-37		-25	-19	-13	-11	-8	-6	-5	-3	-2	0	2	4
25	-35		-23	-17	-11	-8	-5	-4	-2	-1	1	2	4	6
24	-33	-25	-21	-15	-9	-6	-3	-2	0	1	3	5	6	8
23	-31	-23	-18	-13	-7	-4	-1	0	2	4	5	7	9	11
22	-29	-21	-16	-11	-5	-2	1	3	4	6	8	9	11	13
21	-27	-19	-14	-9	-2	0	3	5	7	8	11	12	13	
20	-25	-17	-12	-7	0	3	6	7	9	10	12	14		
19	-23	-15	-10	-5	2	5	8	9	11	13	14			
18	-21	-13	-8	-2	4	7	10	12	13	15				
17	-19	-11	-6	0	6	9	12	14	16					
16	-17	-8	-4	2	8	11	15	16						
15	-15	-6	-2	4	11	14	17	18						
14	-13	-4	0	6	13	16	19							
13	-11	-2	2	8	15	18	21							
12	-9	0	4	10	17	20								
11	-7	2	7	12	19	22								
10	-5	4	9	15	21									
9	-3	6	11	17	24									
8	-1	8	13	19	26									
7	1	10	15	21	28									
6	3	12	17	23	30									
5	5	14	19	25	32									
4	7	16	21	27										
3	9	18	23	29										
2	11	20	25	32										
1	13	22	27											
	Total Air Temperature at ISA (°C)													

Figure 4.3 TAT in ISA conditions

2 Take-Off

2.1 Field Length Limit

The field length limit graph (Figure 4.4) accounts for runway slope, wind component, flap position, aerodrome pressure altitude and ambient temperature. It does not take into account any stopway or clearway and is, therefore, a balanced-field take-off. The field-length used in the graph is based on the minimum V_1 being equal to V_{MCG}. This means that, if either stopway or clearway is available, a certain amount of payload, which could have been carried, will have to be forgone.

2.1.1 The maximum take-off mass is determined as the lowest of:

- the structural limit
- the field length limit
- the climb limit (WAT)
- the tyre speed limit
- the brake energy limit
- the obstacle limit.

2.1.2 The Field Length requirements specified in CS 25 are:

a) If the take-off distance includes a clearway, the take-off run is the greatest of:

i) All power units operating (dry and wet runway). The total of the gross distance from the start of the take-off run to the point at which V_{LOF} is reached, plus one half of the gross distance from V_{LOF} to the point at which the aeroplane reaches 35 ft, all factorised by 1.15 to obtain the net TORR.

ii) One power unit inoperative (dry runway). The horizontal distance from the brakes release point (BRP) to a point equidistant between V_{LOF} and the point at which the aeroplane reaches 35 ft with the critical power unit inoperative.

iii) One power unit inoperative (wet runway). The horizontal distance from the brake release point (BRP) to the point at which the aeroplane is 15ft above the take-off surface, achieved in a manner consistent with the attainment of V_2 by 35ft, assuming the critical power unit inoperative at V_{EF}.

b) The accelerate-stop distance on a wet runway is the greatest of:

i) All engines operating. The sum of the distances required to accelerate from BRP to the highest speed reached during the rejected take-off, assuming the pilot takes the first action to reject the take-off at the V_1 for take-off from a wet runway and to decelerate to a full stop on a wet hard surface, plus a distance equivalent to 2 seconds at the V_1 for take-off from a wet runway.

ii) One engine inoperative. The sum of the distances required to accelerate from BRP to the highest speed reached during the rejected take-off, assuming the critical engine fails at V_{EF} and the pilot takes the first action to reject the take-off at the V_1 for take-off from a wet runway with all engines operating and to decelerate to a full stop on a wet hard surface with one engine inoperative, plus a distance equivalent to 2 seconds at the V_1 for take-off from a wet runway.

iii) The accelerate-stop distance on a dry runway.

c) The take-off distance required is the greatest of the following three distances:

i) All engines operating. 115% of the horizontal distance travelled, with all engines operating, to reach a screen height of 35 ft

ii) One engine inoperative (dry runway). The horizontal distance from BRP to the point at which the aeroplane attains 35 ft, assuming the critical power unit fails at V_{EF} on a dry, hard surface.

iii) One engine inoperative (wet runway). The horizontal distance from BRP to the point at which the aeroplane attains 15 ft, assuming the critical power unit fails at V_{EF} on a wet or contaminated hard surface, achieved in a manner consistent with the achievement of V_2 by 35ft.

2.1.3 **Method of Use of the "Take-Off Performance Field Limit" Graph (Figure 4.4)**

a) Enter with Field Length Available (TORA). Move vertically to the runway slope reference line.

b) Parallel the grid lines to the appropriate runway slope then continue vertically to the wind component reference line.

c) Parallel the grid lines to the appropriate wind component then continue vertically to the flap reference line.

d) If flap is 15°, parallel grid lines then, with a pencil, draw a vertical line through the weight grid. If flap is 5°, with a pencil, draw a vertical line from the reference line through the mass grid.

e) Enter at the aerodrome ambient temperature and proceed vertically to the aerodrome pressure altitude.

f) Proceed horizontally right to the mass grid reference line.

g) From this point interpolate and follow the grid lines to intersect the vertical line drawn in d) above.

h) From this intersection draw a horizontal line to read the Field Length Limited TOM

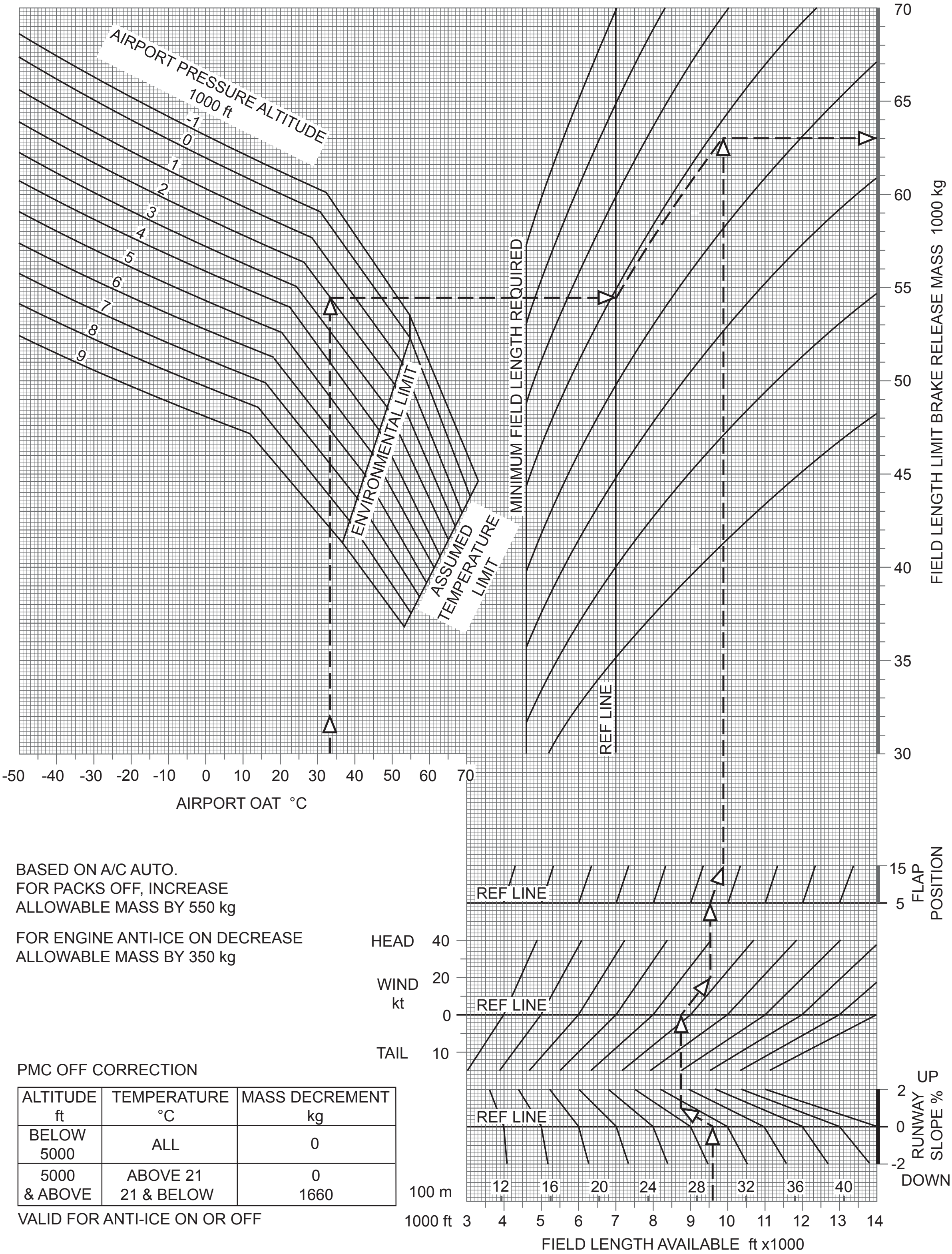
i) Apply any corrections necessary.

Example:

Field Length Available (TORA)	9600 ft
Runway slope	1% Uphill
Wind Component	20 kt Head
Flaps	15°
PMC	ON
Ambient Temperature	+ 33 °C
Aerodrome Pressure Altitude	2,000 ft

Solution:

Field Length Limited TOM	63000 kg



BASED ON A/C AUTO.
FOR PACKS OFF, INCREASE ALLOWABLE MASS BY 550 kg

FOR ENGINE ANTI-ICE ON DECREASE ALLOWABLE MASS BY 350 kg

PMC OFF CORRECTION

ALTITUDE ft	TEMPERATURE °C	MASS DECREMENT kg
BELOW 5000	ALL	0
5000 & ABOVE	ABOVE 21	0
	21 & BELOW	1660

VALID FOR ANTI-ICE ON OR OFF

Figure 4.4 Take-Off Performance – Field Length Limit Graph

2.2 Take-Off Climb

2.2.1 Requirements

During the take-off climb the aeroplane must:

a) Attain the most severe gradient requirement of the take-off Net Flight Path

b) Avoid all obstacles in the obstacle accountability area by the statutory minimum vertical interval.

2.2.2 Use of the Climb Limit Graph (Figure 4.5)

The graph at Figure 4.5 guarantees attainment of the most severe gradient requirement of the net flight path. It does not guarantee obstacle clearance.

Method of Use

a) Enter the graph at aerodrome ambient temperature.

b) Move vertically to the aerodrome pressure altitude.

c) Travel horizontally left to the flap reference line and apply the appropriate setting to read climb limit mass.

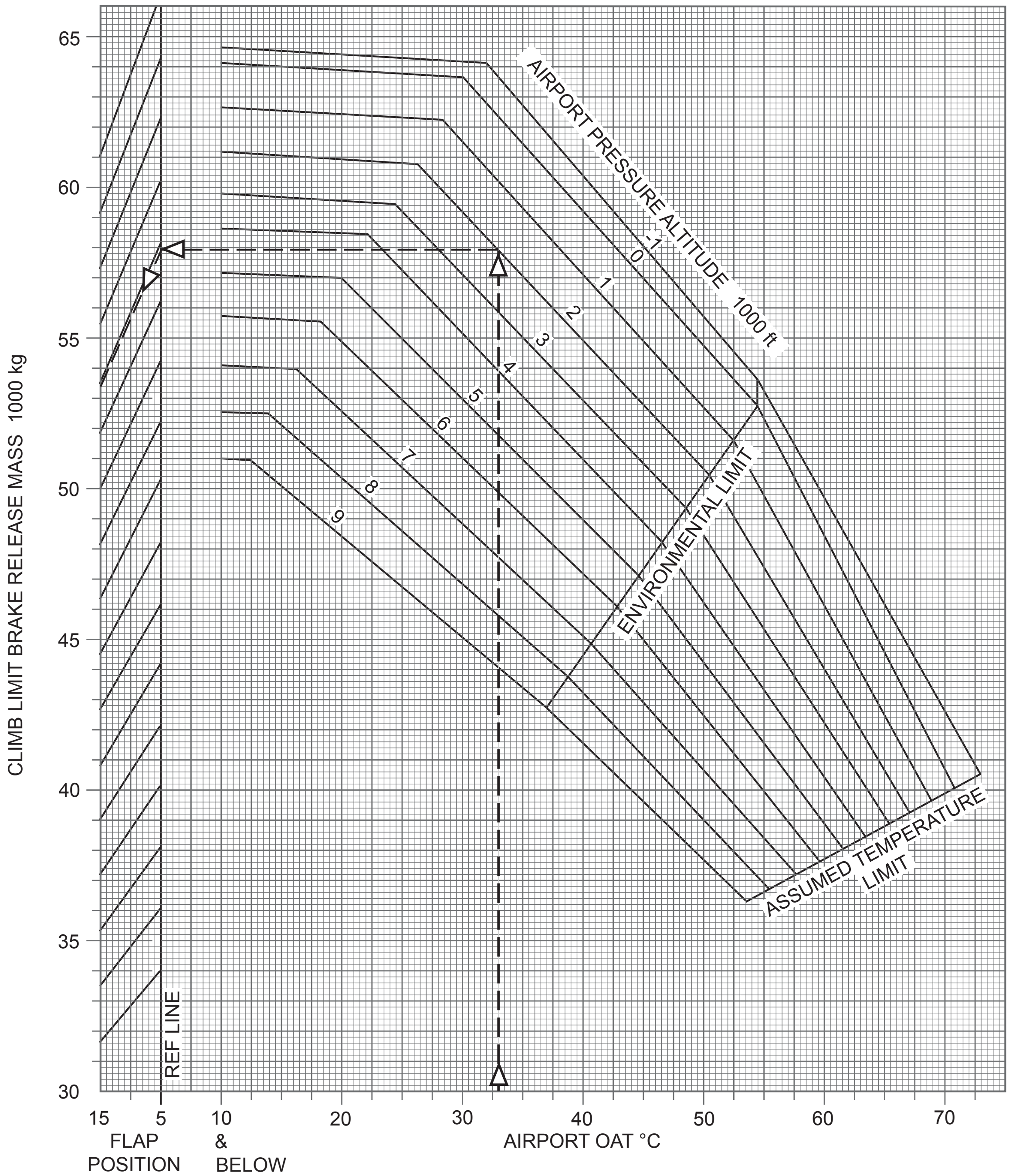
d) Apply any corrections necessary.

Example:

Field Length Available (TORA)	2000 ft
OAT	+ 33°C
Flaps	15°

Solution:

Climb Limited TOM	53400 kg



BASED ON A/C AUTO WITH APU ON OR OFF. FOR PACKS OFF, INCREASE ALLOWABLE MASS BY 900 kg.
FOR OPERATION WITH ENGINE ANTI-ICE ON SUBTRACT 190 kg WHEN AIRPORT PRESSURE ALTITUDE IS AT OR BELOW 8000 ft OR 530 kg WHEN AIRPORT PRESSURE ALTITUDE IS ABOVE 8000 ft.

PMC OFF CORRECTION

ALTITUDE ft	TEMPERATURE °C	MASS DECREMENT kg
BELOW 5000	ALL	0
5000 & ABOVE	ABOVE 21 21 & BELOW	0 1860

Figure 4.5 Take-Off Performance – Climb Limit

2.3 Take-Off Tyre Speed Limit

The graph at Figure 4.6 presents the limitation on take-off weight for 225 mph tyres and 5° flap.

Method of Use

Enter the graph with aerodrome OAT. Proceed vertically to the aerodrome pressure altitude, then horizontally left to read the tyre speed limit.
Correct as necessary.

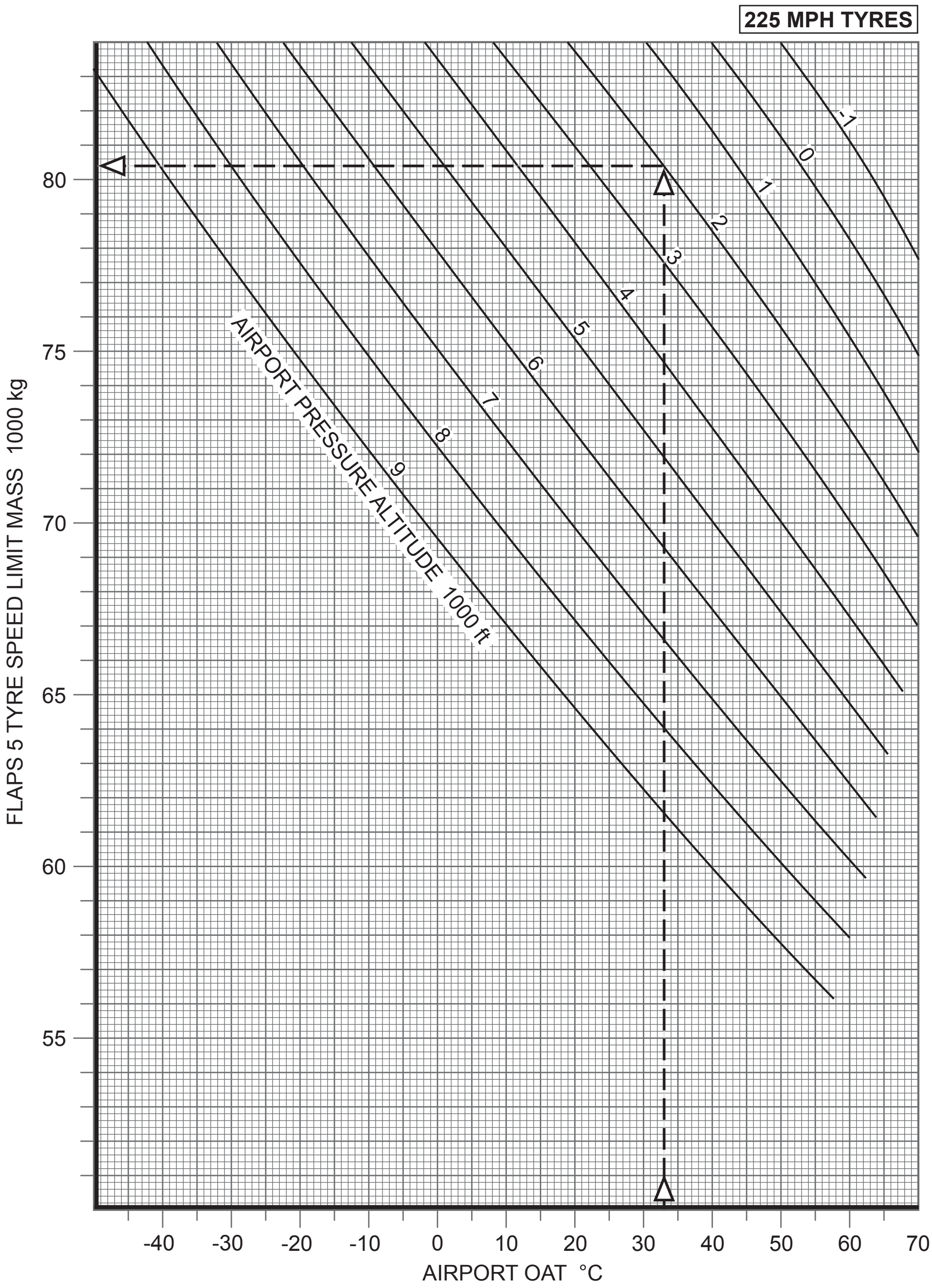
For 210 mph tyres and/or 15° flap, apply the correction below the graph.

Example:

OAT	+ 33°C
Airfield Pressure Altitude	2000 ft
Flaps	15°
PMC	ON
Tyres	210 mph
Uncorrected limit	80400 kg
Correction	-1500 kg

Solution:

Tyre Limit Mass	78900 kg



CONDITIONAL DEVIATION	CORRECTION
15° Flap	+ 6600 kg
210 mph Tyres	- 9600 kg
15° Flap + 210 mph Tyres	- 1500 kg
Headwind	+ 400 kg per kt
Tailwind	-650 kg per kt

PMC OFF CORRECTION

ALTITUDE ft	TEMPERATURE °C	MASS DECREMENT kg
Below 5000	Above 21 21 & Below	250 210
5000 & Above	Above 21 21 & Below	200 270

Figure 4.6 Take-Off Tyre Speed Limit

2.4 Take-Off Brake Energy Limit

Figure 4.7 enables the determination of V_{MBE}.

Generally V_{MBE} will not be limiting except at hot, high aerodromes or operating with a tail wind.

Always check V_{MBE} when outside the shaded area of the top left grid or when there is a tail wind or when employing the improved climb technique. If V_1 exceeds V_{MBE}, apply the correction below the graph. Make $V_1 = V_{MBE}$ and recalculate the other V speeds for the reduced mass.

Method of Use

Enter the graph with aerodrome pressure altitude. Travel horizontally to OAT. Drop vertically to take-off mass, then horizontally right to V_{MBE}.

Example:

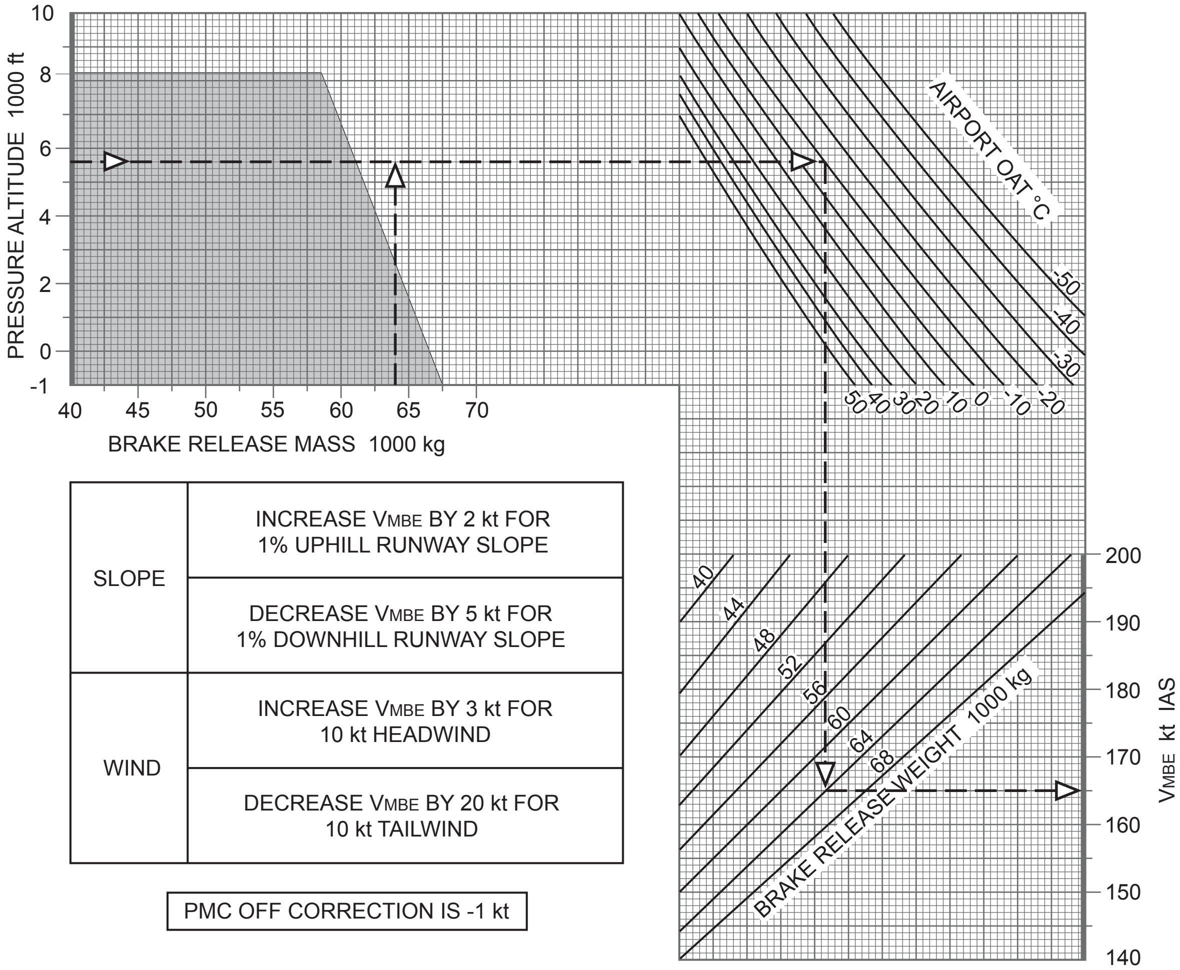
Take-Off Mass	64000 kg
Airfield Pressure Altitude	5600 ft
Ambient Temperature	-10° C
Runway Slope	1.5% Uphill
Wind Component	10 kt Head
PMC	ON

Solution:

V_{MBE} = 165 + 3 + 3 =171 kt

CHECK V_{MBE} WHEN OUTSIDE SHADED AREA OR WHEN
OPERATING WITH TAILWIND OR IMPROVED CLIMB

ALL FLAPS



SLOPE	INCREASE V_{MBE} BY 2 kt FOR 1% UPHILL RUNWAY SLOPE
	DECREASE V_{MBE} BY 5 kt FOR 1% DOWNHILL RUNWAY SLOPE
WIND	INCREASE V_{MBE} BY 3 kt FOR 10 kt HEADWIND
	DECREASE V_{MBE} BY 20 kt FOR 10 kt TAILWIND

PMC OFF CORRECTION IS -1 kt

ADJUST V_{MBE} FOR SLOPE AND WIND

NORMAL TAKE-OFF: DECREASE BRAKE RELEASE MASS BY 300 kg FOR EACH KNOT V_1 EXCEEDS V_{MBE}. DETERMINE NORMAL V_1, V_R, V_2 SPEEDS FOR LOWER BRAKE RELEASE MASS

IMPROVED CLIMB TAKE-OFF: DECREASE CLIMB MASS IMPROVEMENT BY 160 kg FOR EACH KNOT V_1 EXCEEDS V_{MBE}. DETERMINE V_1, V_R, V_2 SPEED INCREMENTS FOR THE LOWER CLIMB MASS IMPROVEMENT

Figure 4.7 Take-Off Brake Energy Limit

2.5 V Speeds and % N_1 Values

The V speeds quoted in Figures 4.8 and 4.9 are those for a balanced-field take-off with no stopway or clearway. The runway is assumed to be hard, level and in still air conditions. Sub-tables are provided to enable V_1 to be corrected for the effects of slope and wind. V_1 can be further adjusted to account for any clearway or stopway by using the following table. This table must not be used if the stopway and/or clearway were used in the determination of the field length limited take-off mass.

2.5.1 V_1 Adjustments

	Normal V_1 KIAS			
Clearway Minus Stopway (ft)	**100**	**120**	**140**	**160**
800	-	-	-3	-2
600	-	-3	-2	-1
400	-4	-3	-2	-1
200	-2	-1	-1	0
0	0	0	0	0
-400	1	1	1	1
-800	1	1	1	1

Maximum Allowable Clearway

Field Length (ft)	**Maximum Allowable Clearway for V_1 Reduction (ft)**
4000	400
6000	500
8000	550
10000	600
12000	700
14000	750

In the absence of more precise details the above table should be used as a guide to the maximum allowable clearway permitted.

In no circumstances may V_1 be less than the V_{MCG} nor may it exceed V_R or V_{MBE}.

2.5.2 The Calculation of V Speeds

To calculate the V speeds use the tables (at Figure 4.8 or 4.9 as appropriate) in the following manner:

a) Enter the density sub-graph (below) with pressure altitude and ambient temperature to determine which of the columns of the tables should be used.

b) Select the tables appropriate to the flap setting from Figure 4.8 or 4.9.

c) Enter the V speed tables at the actual take-off mass. Extract V_1, V_R and V_2.

d) If it is necessary to correct V_1 for slope and/or wind component, enter the table at the top of Figure 4.8 or 4.9, as appropriate, at the actual take-off mass and interpolate the correction necessary.

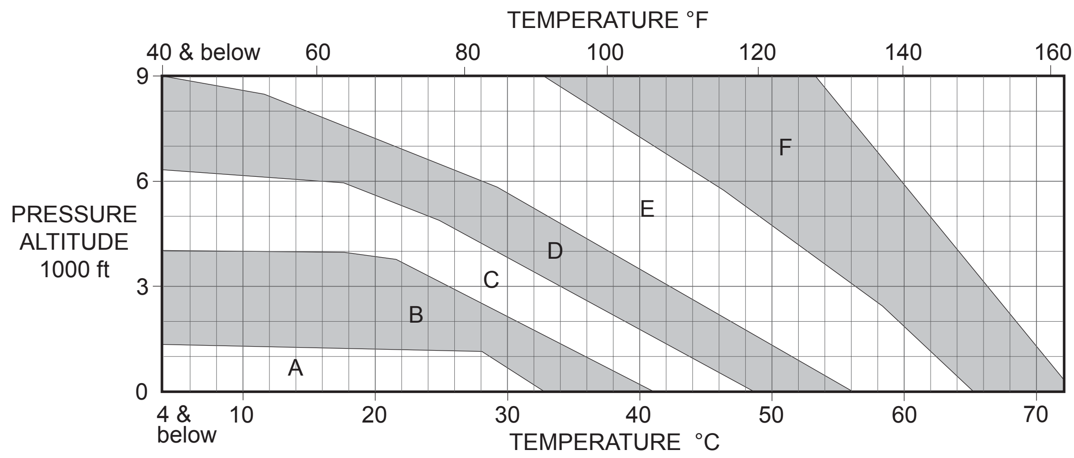
e) Apply the corrections to V_1.

f) Use the sub-table below Figure 4.8 or 4.9, as appropriate, to determine the V_{MCG}. Enter the left column at the ambient temperature and then proceed right along the row to the appropriate aerodrome pressure altitude (interpolating if necessary). Extract V_{MCG}.

g) Compare V_1 with V_{MCG}. If V_1 is less than V_{MCG}, take-off is not permitted.

h) Check TORA exceeds TORR. If it does not, the take-off mass must be reduced.

Density Sub Graph



2.5.3 Stabiliser Trim Setting

To determine the take-off stabiliser trim setting select the appropriate table and use the actual take-off mass and % MAC centre of gravity to read or calculate the appropriate setting.

Figure 4.8 Take-Off Speeds

Flaps 5°

PMC ON

Slope/Wind V_1 adjustment						
Mass (1000 kg)	**Slope %**			**Wind kt**		
	-2	**0**	**2**	**-15**	**0**	**40**
70	-3	0	4	-3	0	1
60	-2	0	2	-3	0	1
50	-2	0	1	-4	0	1
40	-2	0	1	-4	0	1

* V_1 not to exceed V_R

Mass (1000 kg)	**A**			**B**			**C**		
	V_1	V_R	V_2	V_1	V_R	V_2	V_1	V_R	V_2
70	158	163	168	158	164	169			
65	151	155	161	152	156	162	153	157	162
60	144	148	155	145	148	155	146	149	155
55	137	139	149	138	140	149	138	141	148
50	129	131	142	130	132	142	131	133	142
45	121	123	136	122	124	135	122	125	135
40	113	114	130	113	116	129	113	116	128

Mass (1000 kg)	**D**			**E**			**F**		
	V_1	V_R	V_2	V_1	V_R	V_2	V_1	V_R	V_2
70									
65									
60									
55	140	143	148						
50	132	134	141	133	135	141			
45	124	126	135	125	127	134	128	128	134
40	113	117	128	114	118	127	119	120	126

In shaded area check V_{MCG} for actual temp.

V_{MCG}

Actual OAT		**Press. Alt. X 1000 ft**				
°C	**°F**	**0**	**2**	**4**	**6**	**8**
55	131	104				
50	122	107	103			
40	104	111	107	103	99	94
30	86	116	111	107	104	98
20	68	116	113	111	107	102
10	50	116	113	111	108	104
-50	-58	118	115	112	109	105

For A/C packs 'off' increase V_{MCG} by 2 knots

Flaps 5° **Stabiliser Trim Setting**

CG.% MAC	6	10	14	18	22	26	30
Stab. Trim	5½	5	4½	3¾	3¼	2¾	2¼

For masses at or below 45350 kg subtract ½ unit
For masses at or above 61250 kg add ½ unit
Stab trim settings must be between 1 and 5 ¾ units

Figure 4.9 Take-Off Speeds

Flaps 15°

PMC ON

Slope/Wind V_1 adjustment						
Mass (1000 kg)	Slope %			Wind kt		
	-2	0	2	-15	0	40
70	-3	0	4	-3	0	1
60	-2	0	2	-3	0	1
50	-2	0	1	-4	0	1
40	-2	0	1	-4	0	1

* V_1 not to exceed V_R

Mass (1000 kg)	A			B			C		
	V_1	V_R	V_2	V_1	V_R	V_2	V_1	V_R	V_2
70	150	152	158						
65	143	145	152	145	146	151			
60	137	139	146	138	140	146	139	140	146
55	130	131	141	131	132	140	131	133	140
50	122	124	135	123	125	134	124	125	134
45	114	116	128	116	117	128	116	118	128
40	104	107	122	104	109	122	104	110	122

Mass (1000 kg)	D			E			F		
	V_1	V_R	V_2	V_1	V_R	V_2	V_1	V_R	V_2
70									
65									
60									
55	134	134	140						
50	126	126	134	127	128	133			
45	118	119	127	120	120	126	120	121	127
40	109	111	121	111	112	120	112	113	120

In shaded area check V_{MCG} for actual temp.

V_{MCG}

Actual OAT		Press. Alt. X 1000 ft				
°C	°F	0	2	4	6	8
55	131	104				
50	122	107	103			
40	104	111	107	103	99	94
30	86	116	111	107	104	98
20	68	116	113	111	107	102
10	50	116	113	111	108	104
-50	-58	118	115	112	109	105

For A/C packs 'off' increase V_{MCG} by 2 knots

Flaps 15° **Stabiliser Trim Setting**

CG.% MAC	6	10	14	18	22	26	30
Stab. Trim	5	4¼	3¾	3	2½	1¾	1

For masses at or below 45350 kg subtract ½ unit
For masses at or above 61250 kg add ½ unit
Stab trim settings must be between 1 and 5 ¾ units

2.5.4 % N_1 Values

All % N_1 tables may be used for either engine anti-icing 'on' and 'off' configurations. Correction is necessary if the air conditioning packs are off.

To determine the % N_1 values use the following procedure:

a) Select the table appropriate to either PMC on or off.

b) Select the table that is appropriate to the phase of flight (take-off, climb or go-around).

c) Enter the left column of the table with either aerodrome ambient temperature or TAT as appropriate. Read % N_1 in the aerodrome pressure altitude column.

Figure 4.10 Expanded Maximum Take-Off % N_1

Airport OAT		Pressure Altitude ft									
°C	**°F**	**-1000**	**0**	**1000**	**2000**	**3000**	**4000**	**5000**	**6000**	**7000**	**8000**
54	129	93.3	94.1	93.6							
52	126	93.6	94.2	94.2	93.7						
50	122	93.8	94.3	94.3	94.3	93.9					
48	118	94.0	94.5	94.4	94.4	94.4	94.1				
46	115	94.1	94.7	94.6	94.5	94.5	94.6	94.4			
44	111	94.3	94.8	94.8	94.7	94.7	94.7	94.8	94.6		
42	108	94.5	95.0	95.0	94.9	94.9	94.8	94.9	95.0	94.8	
40	104	94.6	95.2	95.2	95.1	95.0	95.1	95.1	95.2	95.1	94.9
38	100	94.8	95.3	95.4	95.3	95.2	95.3	95.3	95.4	95.3	95.2
36	97	95.1	95.5	95.5	95.5	95.4	95.6	95.6	95.6	95.5	95.4
34	93	95.3	95.7	95.7	95.7	95.6	95.8	95.8	95.8	95.7	95.6
32	90	95.5	95.9	95.9	95.8	95.8	96.0	96.0	95.9	95.9	95.8
30	86	95.2	96.1	96.1	96.0	96.0	96.3	96.2	96.1	96.0	96.0
28	82	94.9	95.8	96.3	96.2	96.2	96.5	96.4	96.3	96.2	96.1
26	79	94.6	95.5	96.0	96.4	96.4	96.6	96.5	96.5	96.4	96.3
24	75	94.2	95.2	95.6	96.1	96.5	96.8	96.7	96.7	96.6	96.5
22	72	93.9	94.8	95.3	95.7	96.2	96.9	96.9	96.9	96.8	96.6
20	68	93.6	94.5	95.0	95.4	95.9	96.6	97.1	97.1	97.0	96.9
18	64	93.3	94.2	94.7	95.1	95.6	96.3	96.8	97.3	97.2	97.1
16	61	93.0	93.9	94.3	94.8	95.2	96.0	96.4	96.9	97.4	97.3
14	57	92.6	93.5	94.0	94.4	94.9	95.6	96.1	96.6	97.0	97.5
12	54	92.3	93.2	93.7	94.1	94.6	95.3	95.8	96.3	96.7	97.2
10	50	92.0	92.9	93.4	93.8	94.2	95.0	95.4	95.9	96.4	96.8
8	46	91.7	92.6	93.0	93.4	93.9	94.6	95.1	95.6	96.0	96.5
6	43	91.3	92.2	92.7	93.1	93.6	94.3	94.7	95.3	95.7	96.2
4	39	91.0	91.9	92.4	92.8	93.2	93.9	94.4	94.9	95.3	95.8
2	36	90.7	91.6	92.0	92.4	92.9	93.6	94.1	94.6	95.0	95.5
0	32	90.4	91.2	91.7	92.1	92.6	93.3	93.7	94.2	94.7	95.1
-2	28	90.0	90.9	91.4	91.8	92.2	92.9	93.4	93.9	94.3	94.8
-4	25	89.7	90.6	91.0	91.4	91.9	92.6	93.0	93.5	94.0	94.4
-6	21	89.4	90.2	90.7	91.1	91.5	92.2	92.7	93.2	93.6	94.1
-8	18	89.0	89.9	90.3	90.7	91.2	91.9	92.3	92.8	93.3	93.7
-10	14	88.7	89.6	90.0	90.4	90.8	91.5	92.0	92.5	92.9	93.4
-12	10	88.3	89.2	89.7	90.0	90.5	91.2	91.6	92.1	92.5	93.0
-14	7	88.0	88.9	89.3	89.7	90.2	90.8	91.3	91.8	92.2	92.6
-16	3	87.7	88.5	89.0	89.4	89.8	90.5	90.9	91.4	91.8	92.3
-18	0	87.3	88.2	88.6	89.0	89.5	90.1	90.6	91.1	91.5	91.9
-20	-4	87.0	87.8	88.3	88.7	89.1	89.8	90.2	90.7	91.1	91.6
-22	-8	86.6	87.5	87.9	88.3	88.7	89.4	89.9	90.3	90.8	91.2
-24	-11	86.3	87.1	87.6	88.0	88.4	89.1	89.5	90.0	90.4	90.8
-26	-15	85.9	86.8	87.2	87.6	88.0	88.7	89.1	89.6	90.0	90.5
-28	-18	85.6	86.4	86.9	87.2	87.7	88.4	88.8	89.3	89.7	90.1
-30	-22	85.2	86.0	86.5	86.9	87.3	88.0	88.4	88.9	89.3	89.7

Valid for PMC 'on', A/C 'auto', engine anti-ice 'on' or 'off'
For A/C 'off' Add 1.0% N_1
Do not operate engine anti-ice 'on' at airport OAT above 10°C (50°F).

Figure 4.11 Maximum T/O & Maximum Climb – % N_1 values

PMC ON

Maximum Take-Off % N_1

Valid for 2 packs on (auto) Engine A/I on or off										
Airport OAT		Airport Pressure Altitude (ft)								
°C	°F	0	1000	2000	3000	4000	5000	6000	7000	8000
55	131	93.8	93.8	93.8						
50	122	94.3	94.3	94.3	93.9	93.6				
45	113	94.7	94.7	94.6	94.6	94.6	94.7	94.4	94.2	
40	104	95.2	95.2	95.1	95.0	95.1	95.1	95.2	95.1	94.9
35	95	95.6	95.6	95.6	95.5	95.7	95.7	95.7	95.6	95.5
30	86	96.1	96.1	96.0	96.0	96.3	96.2	96.1	96.0	96.0
25	77	95.3	95.8	96.2	96.5	96.7	96.6	96.6	96.5	96.4
20	68	94.5	95.0	95.4	95.9	96.6	97.1	97.1	97.0	96.9
15	59	93.7	94.2	94.6	95.1	95.8	96.3	96.8	97.2	97.5
10	50	92.9	93.4	93.8	94.2	95.0	95.4	95.9	96.4	96.8
5	41	92.1	92.5	92.9	93.4	94.1	94.6	95.1	95.5	96.0
0	32	91.2	91.7	92.1	92.6	93.3	93.7	94.2	94.7	95.1
-10	14	89.6	90.0	90.4	90.8	91.5	92.0	92.5	92.9	93.4
-20	-4	87.8	88.3	88.7	89.1	89.8	90.2	90.7	91.1	91.6
-30	-22	86.0	86.5	86.9	87.3	88.0	88.4	88.9	89.3	89.7
-40	-40	84.3	84.7	85.1	85.5	86.2	86.6	87.1	87.4	87.9
-50	-58	82.5	82.9	83.2	83.7	84.3	84.7	85.2	85.6	86.0
Do not operate engine anti-ice 'on' at airport OAT above 10°C (50°F)								% N_1 Bleed Adjustment Configuration A/C packs off + 1.0		

Maximum Climb % N_1 250/280/0.74M

Valid for 2 packs on (auto) Engine A/I off										
	TAT(°C)	Airport Pressure Altitude x1000 (ft)								
		0	5	10	15	20	25	30	35	37
	50	90.9	91.1	92.5						
	40	92.0	92.2	93.6	93.3	93.6				
	30	92.2	93.2	93.5	94.2	94.6	94.7			
	20	90.6	92.8	94.3	95.0	95.4	95.6	95.7		
	10	89.1	91.2	93.1	95.1	96.1	96.4	96.6	96.6	96.6
	0	87.5	89.6	91.5	93.4	95.5	97.2	97.5	97.5	97.5
	-10	85.9	87.9	89.8	91.7	93.7	95.9	97.9	98.4	98.4
	-20	84.2	86.3	88.1	90.0	91.9	94.0	96.0	99.0	99.3
	-30	82.5	84.5	86.3	88.2	90.1	92.1	94.1	97.0	97.6
	-40	80.8	82.8	84.5	86.3	88.2	90.2	92.2	95.0	95.6
	-50	79.1	81.0	82.7	84.5	86.3	88.3	90.2	92.9	93.5
% N_1 Corr.	A/C Packs Off	+ 0.5	+ 0.5	+ 0.6	+ 0.7	+ 0.8	+ 0.8	+ 0.9	+ 0.9	+ 0.9
	A/C Packs High	-0.3	-0.3	-0.4	-0.4	-0.4	-0.4	-0.5	-0.6	-0.6
	Engine A/I On	-0.7	-0.8	-0.9	-1.0	-1.0	-1.0	-1.0	-1.0	-1.0
	Wing A/I On	-1.2	-1.2	-1.3	-1.4	-1.6	-1.7	-1.8	-2.0	-2.0

Figure 4.12 Maximum Go-Around – % N_1 values

Maximum Go-Around % N_1

PMC ON

Valid for 2 packs on (auto) Engine A/I on or off											
Airport OAT		TAT	Pressure Altitude (ft)								
°C	°F	°C	0	1000	2000	3000	4000	5000	6000	7000	8000
55	131	58	93.9	93.9	93.9						
50	122	53	94.2	94.2	94.2	94.2	94.2				
45	113	48	94.7	94.6	94.6	94.6	94.6	94.7	94.8	94.6	
40	104	43	95.1	95.1	95.1	95.0	95.1	95.1	95.2	95.1	95.0
35	95	38	95.5	95.6	95.5	95.5	95.7	95.7	95.7	95.6	95.6
30	86	33	96.1	96.1	96.0	96.0	96.3	96.2	96.2	96.1	96.0
25	77	28	95.3	95.8	96.2	96.5	96.7	96.7	96.6	96.5	96.5
20	68	23	94.5	95.0	95.4	95.9	96.6	97.1	97.2	97.0	96.9
15	59	18	93.7	94.1	94.6	95.1	95.8	96.3	96.8	97.3	97.5
10	50	13	92.8	93.3	93.7	94.2	95.0	95.4	96.0	96.6	96.9
5	41	8	92.0	92.5	92.9	93.4	94.1	94.6	95.1	95.6	96.1
0	32	3	91.2	91.7	92.1	92.6	93.3	93.7	94.3	94.7	95.2
-10	14	-8	89.5	90.0	90.4	90.8	91.5	92.0	92.5	93.0	93.4
-20	-4	-18	87.8	88.2	88.6	89.1	89.8	90.3	90.8	91.2	91.6
-30	-22	-28	86.0	86.5	86.9	87.3	88.0	88.5	89.0	89.4	89.8
-40	-40	-38	84.2	84.7	85.1	85.5	86.2	86.6	87.1	87.5	87.9
-50	-58	-48	82.4	82.8	83.2	83.7	84.3	84.7	85.2	85.6	86.0

% N_1 Bleed Adjustment		
	TAT °C	
Configuration	-60	+60
A/C Packs Off	+0.8	+1.0
A/C Packs High	-0.3	-0.3
Wings A/I		
All Engines	-1.3	-1.6
1 Eng. Inop.	-2.3	-2.7

Do not operate engine anti-ice “on” at total air temperature above 10°C (50°F)

Figure 4.13 % N_1 values

Maximum Take-Off % N_1 A/C Packs on (Auto)

PMC OFF

Valid for Engine A/I on or off										
Airport OAT		Airport Pressure Altitude (ft)								
°C	°F	0	1000	2000	3000	4000	5000	6000	7000	8000
55	131	94.9	94.9	94.9						
50	122	95.4	95.4	95.4	95.4	95.4				
45	113	95.9	95.9	95.9	95.9	95.9	95.9	95.9	95.9	
40	104	96.3	96.3	96.3	96.3	96.3	96.3	96.4	96.4	96.4
35	95	96.8	96.8	96.8	96.8	96.8	96.8	96.8	96.8	96.8
30	86	96.6	96.8	97.2	97.2	97.2	97.2	97.2	97.1	97.1
25	77	95.8	96.0	96.5	97.0	97.4	97.6	97.5	97.5	97.4
20	68	95.0	95.2	95.7	96.2	96.5	96.9	97.1	97.1	97.1
15	59	94.1	94.4	94.8	95.4	95.7	96.3	96.3	96.3	96.3
10	50	93.3	93.5	94.0	94.6	94.9	95.2	95.5	95.6	95.7
5	41	92.5	92.7	93.2	93.7	94.0	94.4	94.7	94.8	94.9
0	32	91.7	91.9	92.3	92.9	93.2	93.5	93.8	93.9	94.0
-10	14	90.0	90.2	90.6	91.2	91.5	91.8	92.1	92.2	92.3
-20	-4	88.2	88.4	88.9	89.4	89.7	90.0	90.3	90.4	90.5
-30	-22	86.5	86.7	87.1	87.6	87.9	88.2	88.5	88.6	88.7
-40	-40	84.7	84.9	85.3	85.8	86.1	86.4	86.7	86.8	86.9
-50	-58	82.8	83.0	83.5	83.9	84.2	84.5	84.8	84.9	85.0

Do not operate engine anti-ice “on” at airport OAT above 10°C (50°F)

Maximum Take-Off % N_1 A/C Packs off

Valid for Engine A/I on or off										
Airport OAT		Airport Pressure Altitude (ft)								
°C	°F	0	1000	2000	3000	4000	5000	6000	7000	8000
55	131	95.9	95.9	95.9						
50	122	96.4	96.4	96.4	96.4	96.4				
45	113	96.8	96.8	96.8	96.8	96.8	96.8	96.8	96.9	96.9
40	104	97.3	97.3	97.3	97.3	97.3	97.3	97.3	97.3	97.3
35	95	97.7	97.7	97.7	97.7	97.7	97.7	97.7	97.7	97.7
30	86	97.5	97.7	98.1	98.1	98.1	98.1	98.1	98.1	98.0
25	77	96.7	96.9	97.4	97.9	97.9	97.9	97.9	97.9	97.9
20	68	95.9	96.1	96.6	97.1	97.1	97.1	97.1	97.1	97.1
15	59	95.0	95.3	95.7	96.3	96.3	96.3	96.3	96.3	96.3
10	50	94.2	94.4	94.9	95.6	95.8	96.1	96.3	96.3	96.3
5	41	93.4	93.6	94.1	94.6	94.9	95.2	95.4	95.4	95.4
0	32	92.5	92.7	93.2	93.8	94.1	94.4	94.5	94.5	94.5
-10	14	90.8	91.0	91.5	92.0	92.3	92.6	92.8	92.8	92.8
-20	-4	89.1	89.3	89.7	90.3	90.6	90.9	91.0	91.0	91.0
-30	-22	87.3	87.5	88.0	88.5	88.8	89.1	89.2	89.2	89.2
-40	-40	85.5	85.7	86.1	86.6	86.9	87.2	87.3	87.4	87.4
-50	-58	83.6	83.8	84.3	84.7	85.0	85.3	85.5	85.5	85.5

NOTE: For maximum climb and go-around use PMC 'on' % N_1

Take-Off Speeds Adjustment

Altitude (ft)	Temperature °C (°F)	Speed Adjustment KIAS	
		V_{MCG}	V_1 & V_R
Below 5000	Above 21 (70)	+6	0
	21 (70) & Below	+4	0
5000 & Above	Above 21 (70)	+6	0
	21 (70) & Below	+4	+1

2.6 Contaminated Runway Take-Off Calculations

2.6.1 These calculations assume an engine failure at V_1

2.6.2 Contaminated runway take-offs are prohibited for:

a) Variable or reduced thrust take-offs.

b) Contaminant depths exceeding 13mm (0.5 in) due to spray impingement damage.

2.6.3 The Determination of Take-Off Mass

a) Calculate the normal limiting take-off mass for a dry runway i.e., field length limit, climb limit or obstacle limit.

b) Select the table(s) appropriate to the depth of contaminant (interpolating if necessary).

c) Enter the left column of the top table at the normal limiting take-off mass, travel right to the aerodrome pressure altitude column. Interpolate for mass and pressure altitude, if necessary. Extract the mass reduction. Calculate maximum take-off mass for a contaminated runway by subtracting the mass reduction from the normal limiting take-off mass.

d) If in the shaded area, proceed to the bottom table. Enter the left column with the take-off run available (TORA), move right to the appropriate aerodrome pressure altitude column. Interpolate as necessary. Extract the maximum permissible take-off mass. Make $V_1 = V_{MCG}$.

e) The lower of the two values from c) and d) above is the maximum take-off mass for a contaminated runway.

f) Calculate the V speeds for the **actual** take-off mass.

g) If not in the shaded area in c) above, then re-enter the left table at the **actual** mass to determine the V_1 reduction to be made.

h) Apply the reduction to V_1. If adjusted V_1 is less than V_{MCG}, take-off is not permitted.

Example:

Airfield Pressure Altitude	2000 ft
OAT	+2°C
Flaps	5°
TORA	5800 ft
Runway Slope	2% Down
Wind Component	10 kt Head
TOM	50000 kg
PMC	ON
Runway condition	10 mm Slush

Calculate contaminated runway TOM and V speeds.

Mass & V_1 interpolation for 50,000 kg @ 2000 ft = -7.54 (to 2 dp)
Revised Mass = 42,460 kg
Limiting Mass interpolation for 5800 ft TORA @ 2000 ft
Revised Mass = 44,786 kg
Maximum Take-Off Mass = 42,460 kg
$V_1 = V_{MCG}$ = 114 kt
At 42460 kg, V_R = 119 kt, V_2 = 131 kt

Figure 4.14 Advisory Information – Contaminated Runways

ALL FLAPS

One Engine Inoperative - A/C Auto or off

0.08 Inch (2mm) Slush/Standing Water Depth

Mass x 1000kg	Mass and V_1 Reductions			
	Press Alt (ft)	0	4000	8000
40	1000 kg KIAS	2.9 22	3.4 21	4.0 19
44	1000 kg KIAS	3.7 22	4.2 21	4.9 18
48	1000 kg KIAS	4.3 21	5.0 19	5.8 17
52	1000 kg KIAS	4.9 20	5.7 18	6.5 15
56	1000 kg KIAS	5.6 18	6.3 16	7.0 14
60	1000 kg KIAS	6.1 16	6.8 15	7.3 12
64	1000 kg KIAS	6.6 16	7.2 13	7.6 10
68	1000 kg KIAS	6.9 13	7.5 11	8.2 8

Field Length Available (ft) (TORA)	$V_1 = V_{MCG}$ Limit Mass 1000 kg		
	Pressure Altitude (ft)		
	0	4000	8000
5600 5800 6000	39 42 45	- 34 37	- - -
6200 6400 6600	49 52 55	39 42 45	- - 36
6800 7000 7200	59 62 65	47 50 53	39 41 43
7400 7600 7800	69 - -	56 59 62	46 48 51
8000 8200 8400	- - -	65 68 71	53 56 58
8600 8800 9000	- - -	- - -	61 64 66

Figure 4.14 Continued Advisory Information – Contaminated Runways

ALL FLAPS

One Engine Inoperative – A/C Auto or off

0.25 Inch (6mm) Slush/Standing Water Depth

Mass x 1000kg	Mass and V_1 Reductions			
	Press Alt (ft)	0	4000	8000
40	1000 kg KIAS	3.4 19	4.0 16	4.9 12
44	1000 kg KIAS	4.3 18	5.3 14	6.3 10
48	1000 kg KIAS	5.3 16	6.3 12	7.5 9
52	1000 kg KIAS	6.2 13	7.2 10	8.4 8
56	1000 kg KIAS	7.0 11	8.1 8	9.1 7
60	1000 kg KIAS	7.9 8	8.8 7	9.5 6
64	1000 kg KIAS	8.7 7	9.4 5	9.7 5
68	1000 kg KIAS	9.4 5	9.9 5	9.7 5

Field Length Available (ft) (TORA)	$V_1 = V_{MCG}$ Limit Mass 1000 kg		
	Pressure Altitude (ft)		
	0	4000	8000
5400 5600 5800	40 43 47	- 35 38	- - -
6000 6200 6400	50 53 56	41 43 46	- 36 38
6600 6800 7000	59 63 66	48 51 54	41 43 45
7200 7400 7600	70 - -	57 60 63	48 50 52
7800 8000 8200	- - -	65 68 -	55 57 59
8400 8600 8800	- - -	- - -	62 64 67

Figure 4.14 Continued Advisory Information – Contaminated Runways

ALL FLAPS

One Engine Inoperative – A/C Auto or off

0.5 Inch (13mm) Slush/Standing Water Depth

Mass x 1000kg	Mass and V_1 Reductions			
	Press Alt ft	**0**	**4000**	**8000**
40	1000 kg KIAS	4.2 13	5.0 6	6.5 0
44	1000 kg KIAS	5.5 9	6.8 2	8.5 0
48	1000 kg KIAS	6.8 4	8.8 0	10.3 0
52	1000 kg KIAS	8.2 1	10.2 0	11.8 0
56	1000 kg KIAS	9.5 0	11.4 0	12.7 0
60	1000 kg KIAS	11.5 0	12.5 0	13.1 0
64	1000 kg KIAS	15.0 0	13.2 0	13.0 0
68	1000 kg KIAS	13.8 0	13.8 0	12.4 1

Field Length Available (ft) (TORA)	$V_1 = V_{MCG}$ Limit Mass 1000 kg		
	Pressure Altitude (ft)		
	0	**4000**	**8000**
5000 5200 5400	38 41 44	- 35 37	- - -
5600 5800 6000	48 51 54	40 42 45	- 36 38
6200 6400 6600	56 59 62	47 50 52	40 42 44
6800 7000 7200	65 68 70	55 57 60	47 49 51
7400 7600 7800	- - -	62 64 67	53 55 58
8000 8200 8400	- - -	69 - -	60 62 65

2.7 Increased V_2 Take-Off

If the maximum take-off mass is limited by the minimum acceptable climb gradients of the net flight path, and there is a large excess of available field length over that which is required, then it is possible to improve the take-off weight and still attain the minimum climb gradient requirement (subject to the limitations of the tyre speed and field length limitations). This is done by holding the aeroplane on the ground until it reaches an increased V_R and climbing at an increased V_2, which equates to V_x (the speed that will attain the maximum climb gradient).

2.7.1 Method of Use of Figure 4.15

a) Select the set of graphs appropriate to the flap setting on the "improved climb performance field length limit" graph (Figure 4.15).

b) Enter the relevant left-hand graph with the value of the field length limit mass minus the climb limit mass. Travel vertically up to the normal 'climb limit' mass line.

c) From this intersection move horizontally left to the vertical axis to read the climb mass improvement and horizontally right to the vertical axis to read the increase to apply to V_1.

d) Continue horizontally right to the reference line of the right-hand graph. From this point interpolate and follow the grid lines to reach a vertical input in the right-hand graph of the normal climb limit mass.

e) From this intersection, travel horizontally right to the vertical axis to read the increase to apply to V_R and V_2.

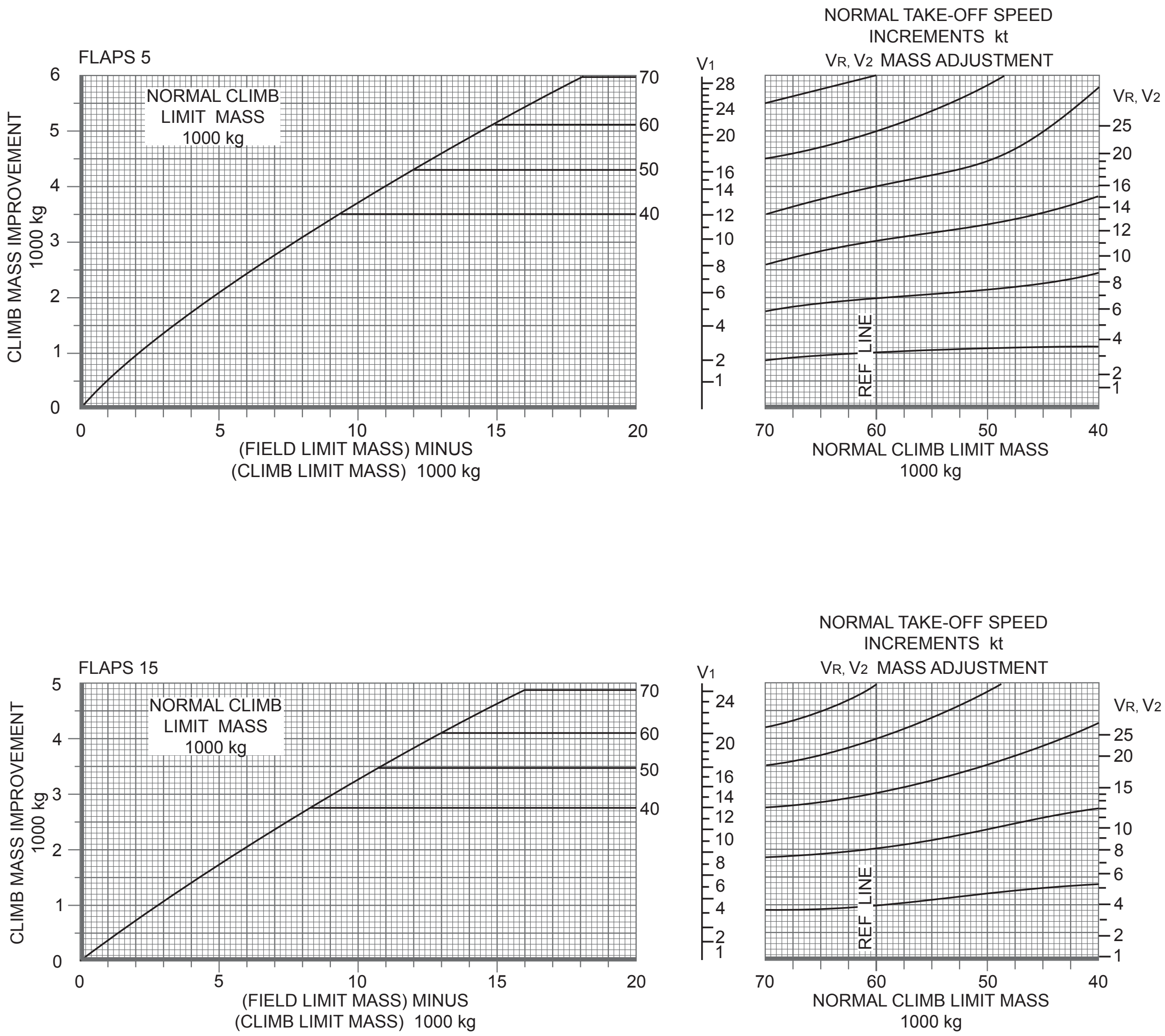
f) Repeat this process in the improved climb performance tyre speed limit graph (Figure 4.16) except that the initial entry point is the tyre limit mass minus the climb limit mass.

g) The lower of the two mass increases is that which must be used together with its associated speed increases.

h) Add the mass increase to the normal climb mass limit.

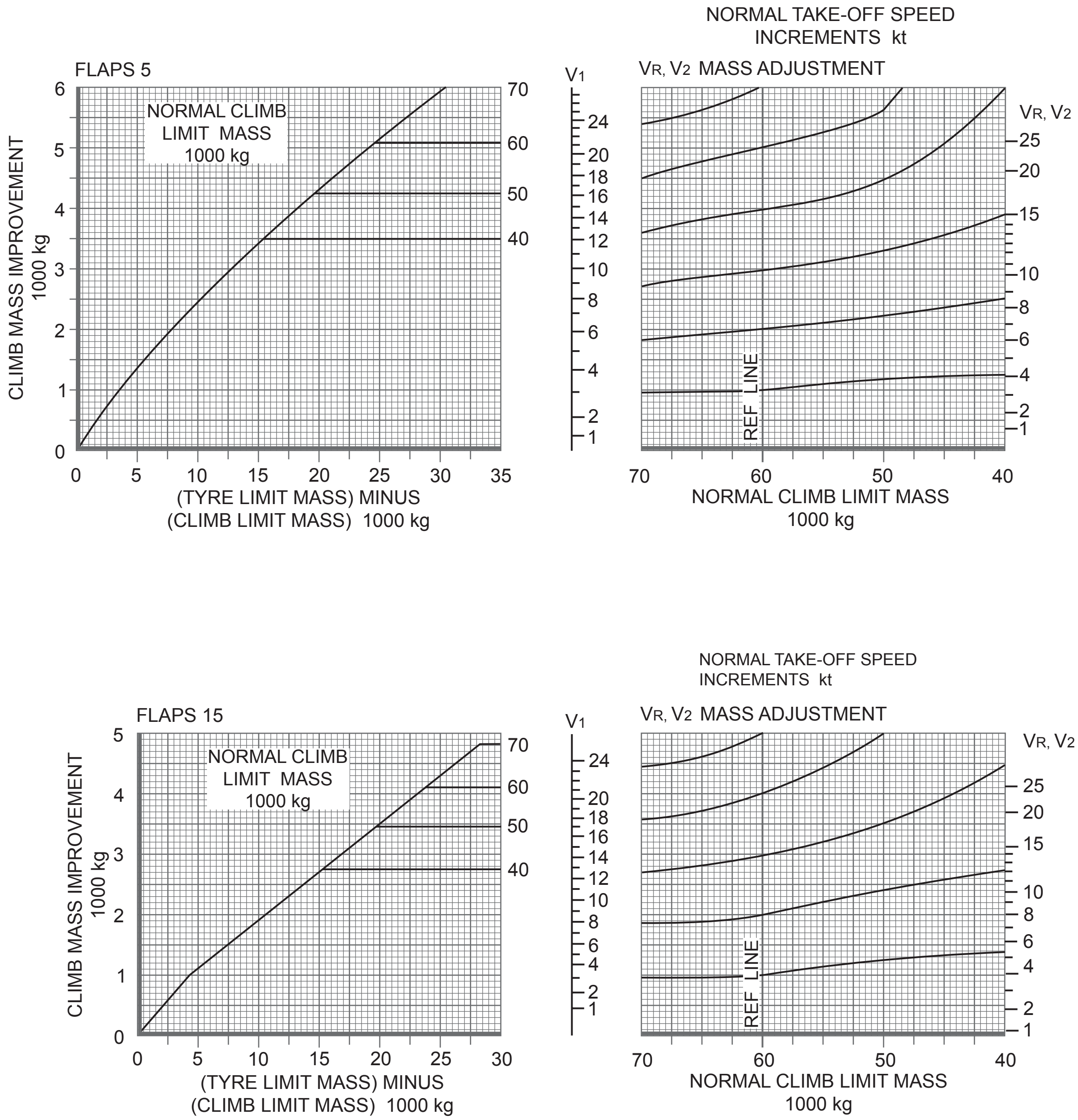
i) Determine the V speeds for this increased mass.

j) Apply the speed increases to the appropriate speeds. Check V_{MBE}.



USE SMALLER OF IMPROVED CLIMB MASS (FIELD LENGTH LIMITS) OR (TYRE SPEED LIMITS)
APPLY SPEED INCREMENTS TO NORMAL V_1, V_R, V_2 FOR ACTUAL TAKE-OFF MASS
CHECK BRAKE ENERGY LIMITS

Figure 4.15 Improved Climb Performance – Field Length Limit



USE SMALLER OF IMPROVED CLIMB MASS (FIELD LENGTH LIMITS OR TYRE SPEED LIMITS)
APPLY SPEED INCREMENTS TO NORMAL V_1, V_R, V_2 FOR ACTUAL TAKE-OFF MASS
CHECK BRAKE ENERGY LIMITS

Figure 4.16 Improved Climb Performance – Tyre Speed Limit

2.8 Reduced Thrust Take-Off

The reduced thrust take-off procedure is referred to by a number of different names such as the 'Variable Thrust Take-Off' or the 'Assumed Temperature Take-Off'. It is a technique employed to preserve engine life or reduce the noise generated at take-off.

This technique can only be used when the available distance greatly exceeds that which is required. The maximum reduction in thrust permitted is 25% of that required for a normal take-off.

2.8.1 Restrictions

A reduced thrust take-off is not permitted with:

- icy or very slippery runways
- contaminated runways
- anti-skid unserviceable
- reverse thrust unserviceable
- increased V_2 procedure
- the PMC off.

2.8.2 Calculation Procedure

It is first necessary to determine the most limiting performance condition. The only common parameter to enable comparison is that of temperature. Thus the maximum permissible temperature must be calculated for the actual take-off mass from each of the following:

- field limit graph
- climb limit graph
- tyre-speed limit graph
- obstacle limit graph

From these temperatures, select the lowest and ensure that it does not exceed the environmental limit. If it does, then the environmental limit becomes the assumed temperature.

2.8.3 Chart Procedure

a) Calculate the maximum assumed temperature from Figure 4.17a or b, as appropriate. Enter the left column with the actual ambient temperature and read the maximum temperature in the column appropriate to the aerodrome pressure altitude.

b) From Figure 4.17c on bottom line, determine the minimum assumed temperature for the aerodrome pressure altitude.

c) From the same table, for the assumed temperature to be used, determine the maximum take-off % N_1. Add 1.0% N_1 if air conditioning packs are off. The assumed temperature used must neither exceed the maximum from paragraph a) above or be below the minimum from paragraph b) above.

d) Enter the left column of Figure 4.17d with assumed temperature minus ambient temperature. Travel right along the line to the column appropriate to the ambient temperature, interpolating if necessary. Read the % N_1 adjustment.

e) Subtract the value determined at paragraph d) from that at paragraph c) to determine the % N_1 to be set at take-off.

PMC ON

Assumed temp. % N1 = Maximum Take-Off % N1 minus % N_1 adjustment

Maximum Assumed Temperature °C[1]

OAT °C	Press. Alt 1000 (ft)								
	0	1	2	3	4	5	6	7	8
55	71	71							
50	69	68	68	69	70				
45	67	66	66	67	67	67	68	70	
40	65	64	64	64	64	64	64	66	68
35	63	62	62	62	61	61	62	63	64
30	61	60	60	59	59	59	59	60	61
25	61	59	58	57	56	56	56	57	58
20	61	59	58	57	55	53	54	54	55
15 & below	61	59	58	57	55	53	53	52	52

Figure 4.17 a Assumed Temperature Reduced Thrust

1. Based on 25% Take-Off Thrust Reduction

Maximum Assumed Temperature °F[1]

OAT °F	Press Alt. 1000 (ft)								
	0	1	2	3	4	5	6	7	8
130	159	159							
120	155	154	154	155	157				
110	151	149	149	150	151	151	152	155	
100	148	145	145	145	145	147	145	149	151
90	143	141	141	140	140	140	140	143	144
80	142	139	138	136	135	135	135	137	138
70	142	138	136	135	131	129	129	130	132
60 & below	142	138	136	135	131	127	127	126	126

Figure 4.17 b Assumed Temperature Reduced Thrust

1. Based on 25% Take-Off Thrust Reduction

PMC ON

Maximum Take-Off % N_1

Valid for 2 packs on (auto) Engine A/I on or off						For A/C off add 1.0% N_1				
Assumed Temp		Airport Pressure Altitude (ft)								
°C	°F	0	1000	2000	3000	4000	5000	6000	7000	8000
75	167	85.4	85.4							
70	158	87.6	87.4	87.4	87.6					
65	149	89.7	89.4	89.2	89.2	89.2	89.3	89.5	89.9	90.4
60	140	91.8	91.3	91.0	90.8	90.7	90.7	90.8	91.1	91.4
55	131	93.8	93.2	92.7	92.4	92.1	92.1	92.0	92.1	92.3
50	122	94.3	94.3	94.3	93.9	93.6	93.4	93.2	93.2	93.2
45	113	94.7	94.7	94.6	94.6	94.6	94.7	94.4	94.2	94.0
40	104	95.2	95.2	95.1	95.0	95.1	95.1	95.2	95.1	94.9
35	95	95.6	95.6	95.6	95.5	95.7	95.7	95.7	95.6	95.5
30	86	96.1	96.1	96.0	96.0	96.3	96.2	96.1	96.0	96.0
25	77		96.6	96.5	96.5	96.7	96.6	96.6	96.5	96.4
20	68					97.1	97.1	97.1	97.0	96.9
15	59							97.6	97.5	97.5
Minimum Assumed Temp. °C (°F)		30 (86)	28 (82)	26 (79)	24 (75)	22 (72)	20 (68)	18 (64)	16 (61)	15 (59)

Figure 4.17 c Assumed Temperature Reduced Thrust

% N_1 Adjustment for Temperature Difference

Assumed Temp. Minus OAT		Outside Air Temperature														
		°C	-40	-20	0	5	10	15	20	25	30	35	40	45	50	55
°C	°F	°F	-40	-4	32	41	50	59	68	77	86	95	104	113	122	131
10	18						1.6	1.6	1.6	1.5	1.5	1.5	1.5	1.4	1.4	1.3
20	36				3.3	3.2	3.2	3.1	3.0	3.0	2.9	2.8	2.8	2.7	2.5	2.3
30	54				4.8	4.8	4.6	4.5	4.4	4.3	4.0	3.8	3.6	3.6	3.6	3.6
40	72			6.0	6.2	6.1	6.0	5.8	5.7	5.2	5.0	5.0				
50	90			8.2	7.5	7.3	7.2	6.6	6.5							
60	108		10.4	9.5	8.7	8.1	7.9									
70	126		11.8	10.7	9.3											
80	144		13.0	11.8	10.1											
90	162		14.0	12.4												
100	180		15.0	12.8												
110	198		15.4													

Figure 4.17 d Assumed Temperature Reduced Thrust

2.9 **Anti-Skid Inoperative (Simplified method)**

Because the accelerate/stop distance will be adversely affected if the anti-skid is inoperative, V_1 has to be reduced to comply with the take-off requirements. This will increase the take-off distance required beyond that which would normally be required and thus decrease the distance to any obstacles encountered after take-off.

2.9.1 **Simplified Calculation Method**

a) Decrease the normal runway/obstacle limited take-off weight by 7700 kg.

b) Recalculate the V speeds for this reduced mass.

c) Further reduce V_1 by the amount shown in the table at Figure 4.18.

Anti-Skid Inoperative V_1 Decrements	
Field length (ft)	**V_1 Reduction (kt)**
6000	28
8000	21
10,000	17
12,000	14
14,000	11

Figure 4.18 V_1 Decrements

d) If the actual take-off mass is already less than the anti-skid inoperative limited take-off mass ensure V_1 does not exceed the anti- skid operative V_1.

e) If V_1 is less than V_{MCG} (see Figure 4. 19) and if ASDA exceeds 7900 ft, set $V_1 = V_{MCG}$.

f) Always ensure V_1 is not less than V_{MCG} shown in Figure 4.19.

Max Take-Off Thrust **V_{MCG}**

OAT		**Pressure Altitude (Ft)**					
°C	**°F**	**0**	**2000**	**4000**	**6000**	**8000**	**9000**
55	131	105					
50	122	107	103				
45	113	109	105	101	96		
40	104	111	107	103	99	94	
35	95	113	109	105	101	96	94
30	86	116	111	107	104	98	96
25	77	116	113	109	105	100	98
20	68	116	113	111	107	102	100
15	59	116	113	111	108	104	102
-50	-58	118	115	112	109	105	104

Figure 4.19 V_{MCG}

For packs 'OFF' add 2 kt

3 Obstacle Clearance

These graphs are provided for Flaps 5° and Flaps 15° (Figures 4.20 and 4.21). They provide a rapid means of obtaining the value of obstacle clearance after take-off. They are intended for use when a detailed airport analysis is not available. Detailed analysis for the specific case from the aeroplane flight manual may result in a less restrictive weight and can account for the non-use of the air conditioning packs.

These graphs are not valid for A/C packs off or for take-offs using the improved climb technique.

3.1 Obstacle-Limit Mass Determination

a) Select the graph appropriate to the flap setting.

b) Adjust the obstacle elevation to account for runway slope to determine obstacle height as shown on Figure 4.20 and Figure 4.21.

c) Enter the bottom left vertical axis at the adjusted obstacle height.

d) Travel horizontally right to intersect the horizontal distance of the obstacle measured from the brake release point.

e) From this intersection, move vertically up to the ambient temperature reference line, then parallel the grid lines to the appropriate temperature.

f) Continue vertically to the aerodrome pressure altitude reference line. Parallel the grid lines to the appropriate pressure altitude before continuing vertically to the wind component reference line.

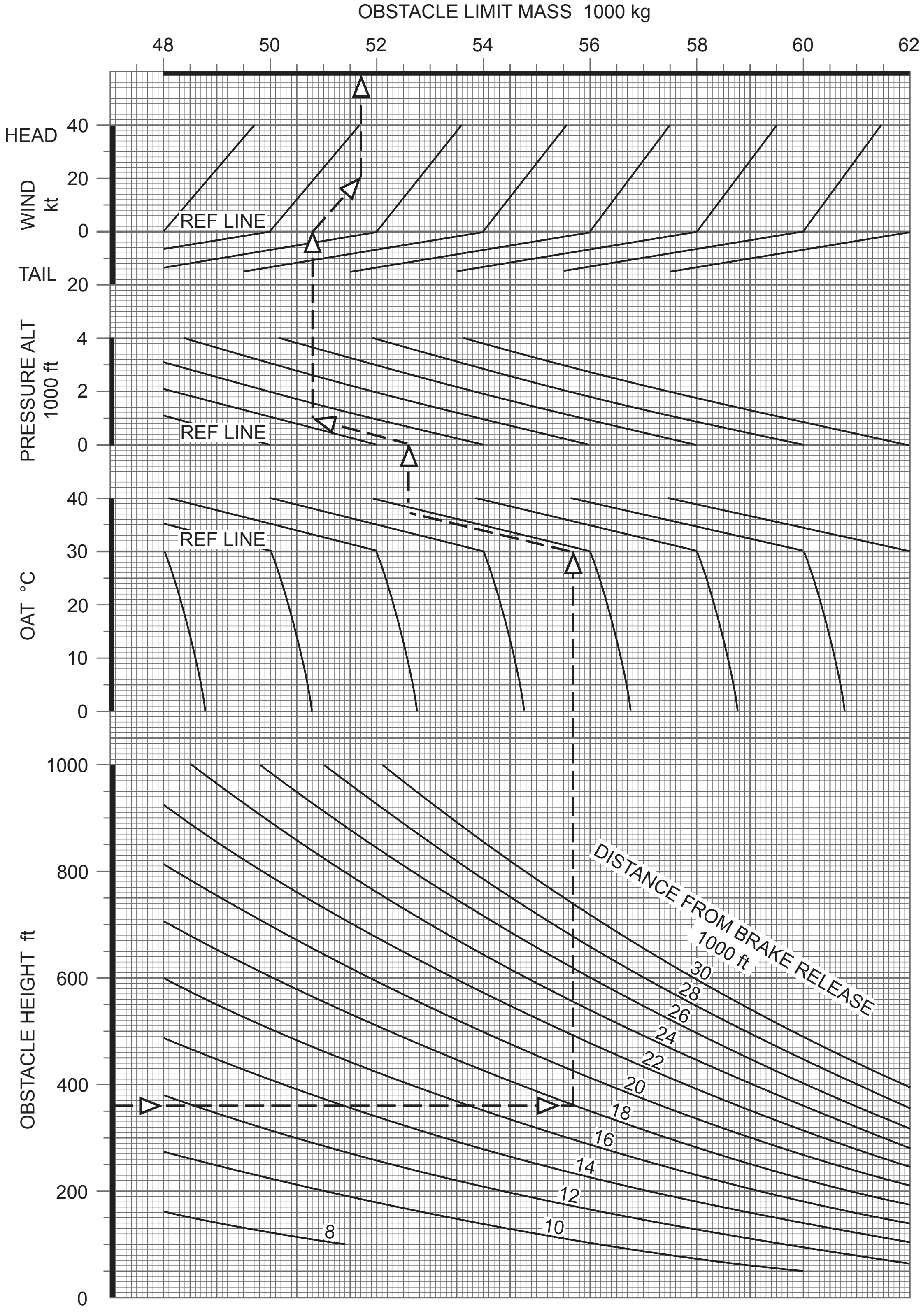
g) Parallel the grid lines from this point to the value of the wind component then continue vertically to read the obstacle limited take-off mass.

Example:

Flap Setting	5°
Aerodrome Pressure Altitude	1,000 ft
Ambient Temperature	+ 37°C
PMC	ON
Wind Component.	20 kt Head
Runway Slope	2% down
Obstacle Distance from BRP	18,000 ft
Obstacle Elevation	1,160 ft
Take-Off Distance Required	10,000 ft

Solution:

Obstacle Height =	1160 - [1000 - (10000 x 2%)] = 360 ft
Obstacle Limited TOM =	51,700 kg

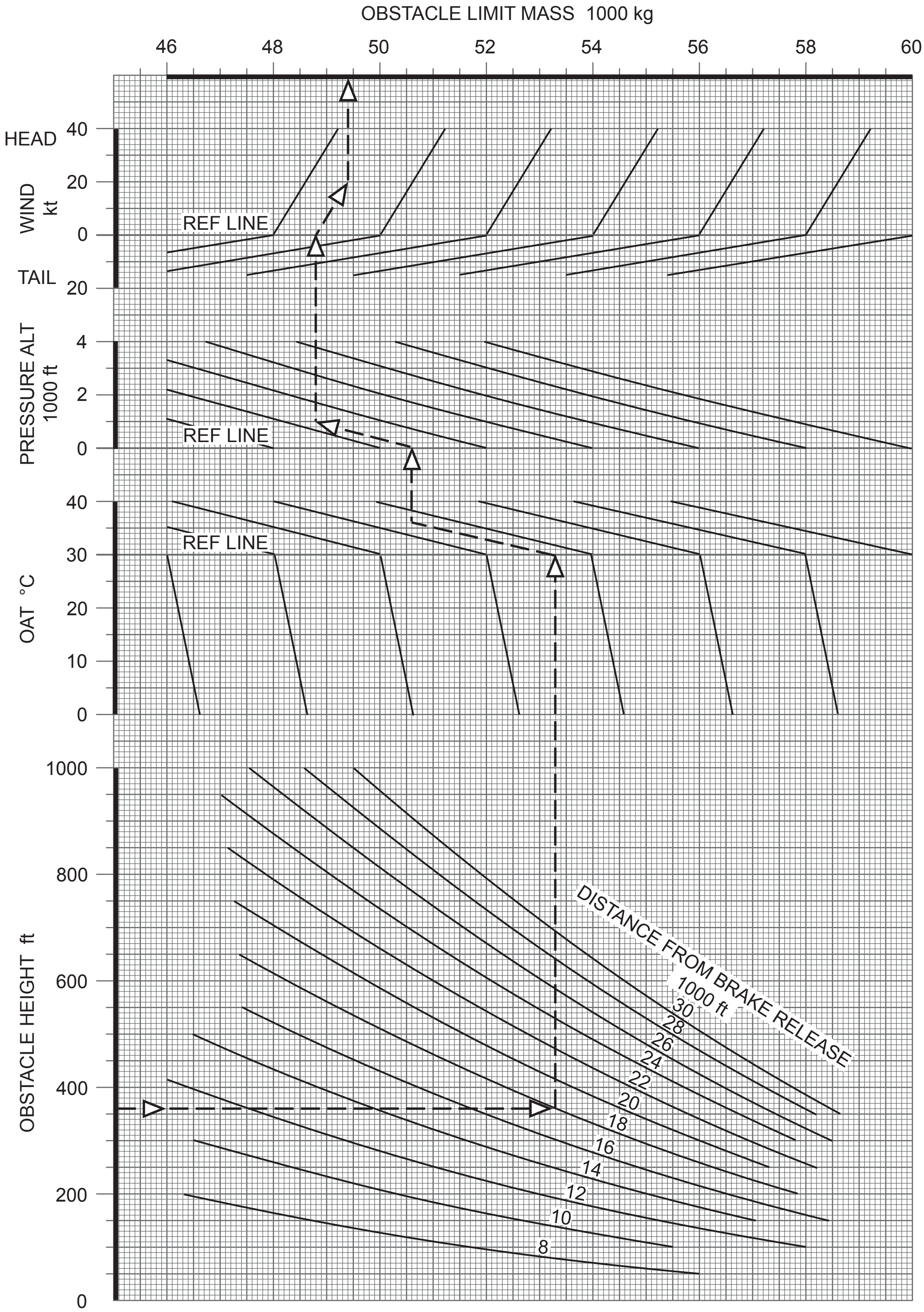


PMC OFF CORRECTION

TEMPERATURE °C	MASS DECREMENT kg
21.1 & BELOW	4970
ABOVE 21.1	4420

OBSTACLE HEIGHT MUST BE CALCULATED FROM THE LOWEST POINT OF THE RUNWAY TO CONSERVATIVELY ACCOUNT FOR RUNWAY SLOPE

Figure 4.20 Obstacle Limits – Flaps 5°



PMC OFF CORRECTION

TEMPERATURE °C	MASS DECREMENT kg
21.1 & BELOW	4970
ABOVE 21.1	4420

OBSTACLE HEIGHT MUST BE CALCULATED FROM THE LOWEST POINT OF THE RUNWAY TO CONSERVATIVELY ACCOUNT FOR RUNWAY SLOPE

Figure 4.21 Obstacle Limits – Flaps 15°

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4 En-route

4.1 Maximum % N_1 Value

In the event of an engine failure during the cruise, it will generally be necessary to reduce speed and descend to a lower altitude. This is accomplished by setting maximum continuous thrust on the remaining live engine and allowing the speed to reduce, while maintaining altitude, to the optimum drift-down speed. One engine inoperative information is based upon one pack operating with the A/C switch on "auto" or "high".

The initial maximum continuous $\%N_1$ setting, with normal engine bleed for air conditioning, one pack on, following engine failure in the cruise for 0.74 Mach, may be determined from the upper table of Figure 4.22. The drift down speed and level off altitude (stabilising altitude) may be determined from the lower table of Figure 4.22, for specific weights and temperature deviation. This is the **gross** level-off altitude.

4.2 Level Off Altitude

For performance planning purposes the level off altitude should be determined from Figure 4.23. This is based on the **net** one engine inoperative performance (i.e. gross gradient -1.1%).

Figure 4.22 Driftdown

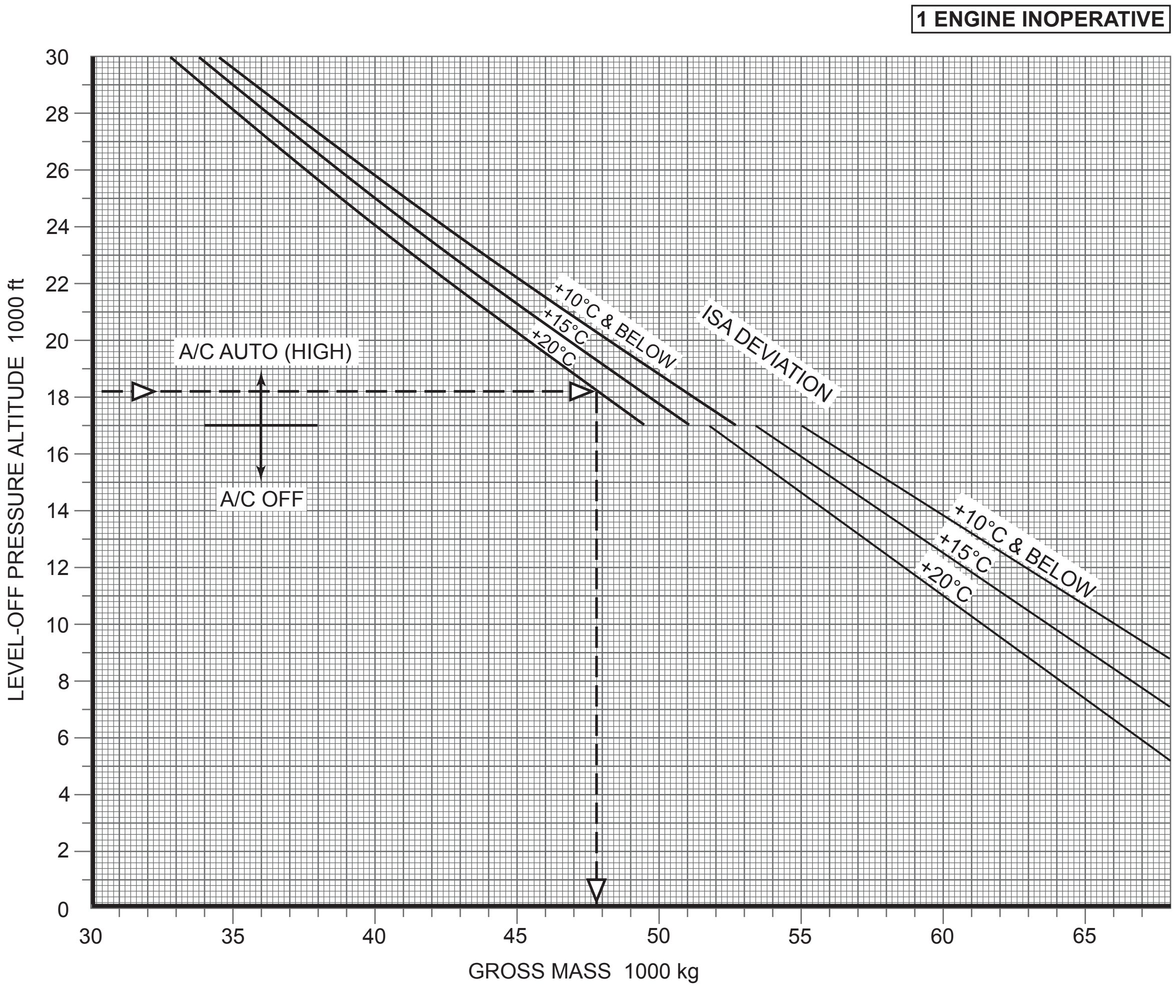
Optimum Driftdown Speed One Engine Inoperative

Initial Maximum Continuous % N_1 0.74 Mach A/C Auto (High)

	TAT °C												
Pressure Altitude (ft)	**-50**	**-40**	**-30**	**-25**	**-20**	**-15**	**-10**	**-5**	**0**	**5**	**10**	**15**	**20**
37,000	93.0	95.0	97.0	98.0	98.7	98.3	98.0	97.6	97.0	96.5	96.0	95.7	95.1
35,000	92.4	94.5	96.5	97.5	98.4	98.3	98.0	97.6	97.0	96.5	96.0	95.7	95.1
33,000	91.5	93.5	95.5	96.5	97.4	98.4	98.1	97.7	97.1	96.6	96.1	95.8	95.2
31,000	90.3	92.3	94.3	95.3	96.2	97.1	98.1	97.7	97.1	96.6	96.1	95.8	95.2
29,000	89.3	91.3	93.2	94.1	95.1	96.0	96.9	97.7	97.1	96.6	96.1	95.8	95.2
27,000	88.1	90.1	92.0	92.9	93.9	94.8	95.7	96.6	97.1	96.6	96.1	95.8	95.2

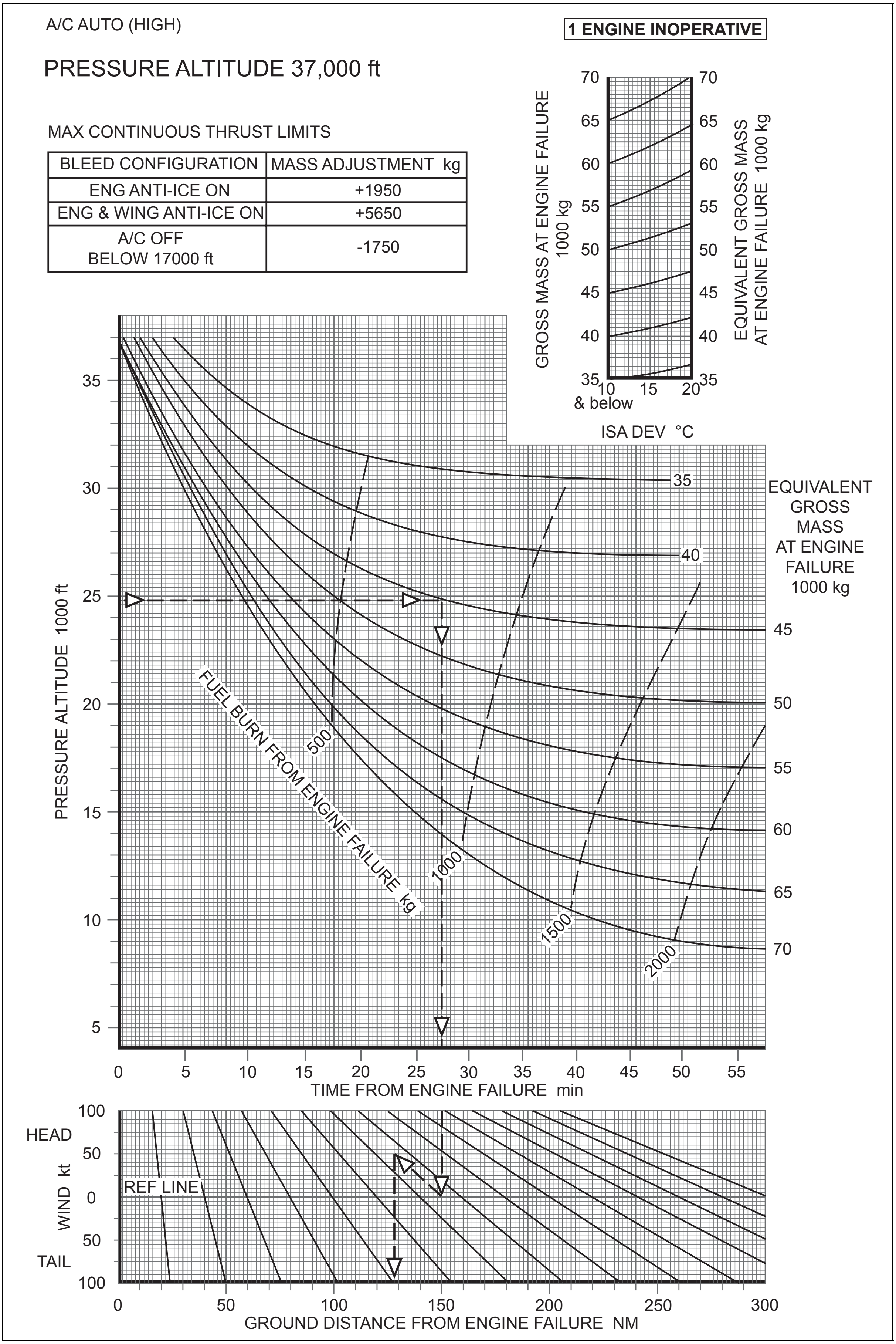
DriftDown Speed/Level Off

Mass (1000 kg)		Optimum Driftdown Speed KIAS	Level Off Altitude (ft)		
Start driftdown	**Level off**		**ISA + 10°C & below**	**ISA + 15°C**	**ISA + 20°C**
70	67	245	14,200	12,900	11,400
65	62	237	16,700	15,500	14,200
60	57	228	19,200	18,200	17,000
55	52	218	21,900	20,900	19,800
50	48	209	24,800	23,800	22,800
45	43	198	27,700	26,900	26,000
40	38	187	30,700	30,100	29,300
35	33	175	33,900	33,400	32,700



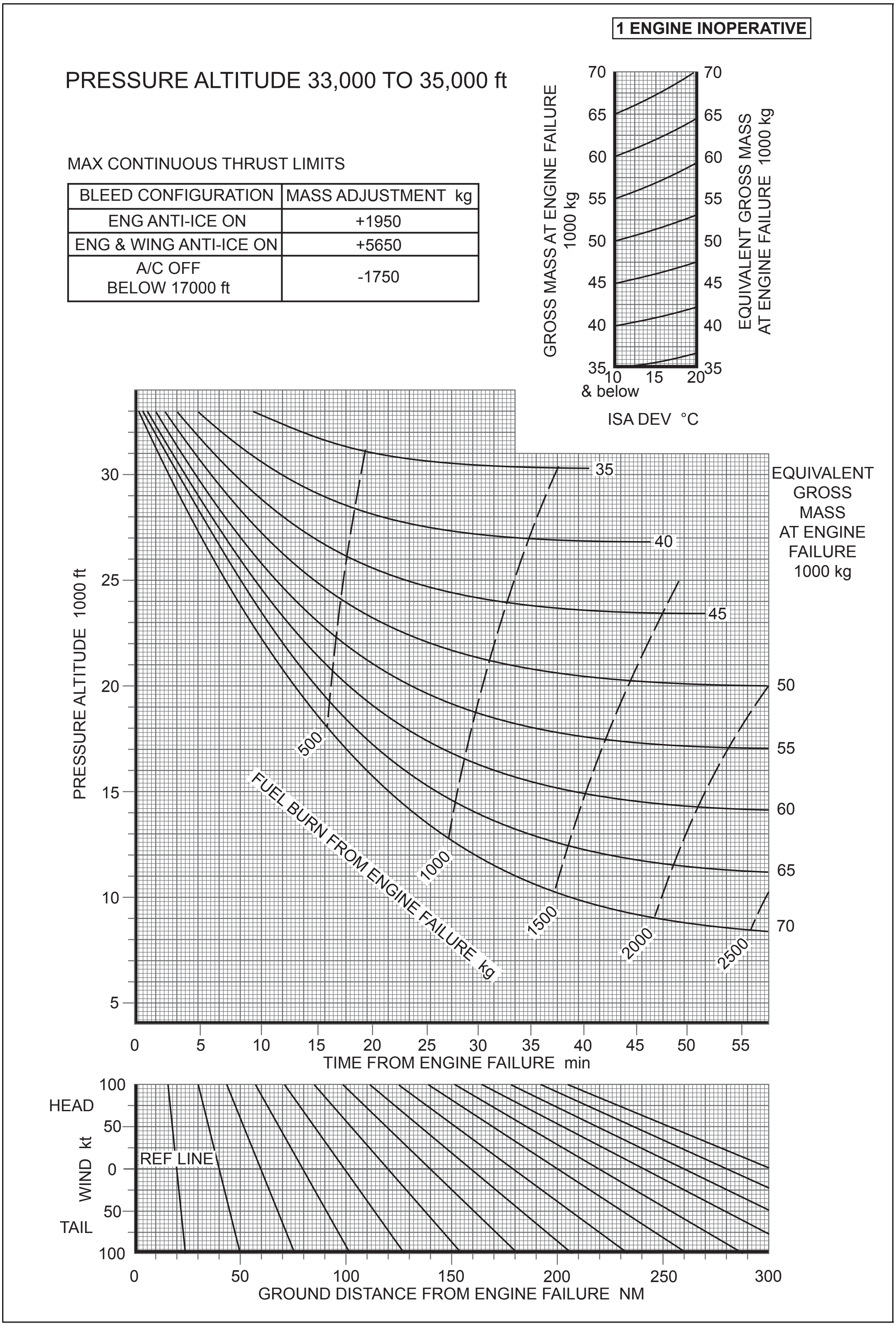
BLEED CONFIGURATION	MASS ADJUSTMENT kg
ENG ANTI-ICE ON	-1950
ENG & WING ANTI-ICE ON	-5650
A/C AUTO (HIGH) BELOW 17,000 ft	-2500

Figure 4.23 Net Level-Off Altitude



BLEED CONFIGURATION	MASS ADJUSTMENT kg
ENG ANTI-ICE ON	+1950
ENG & WING ANTI-ICE ON	+5650
A/C OFF BELOW 17000 ft	-1750

Figure 4.24 Driftdown Profiles – Net Flight Path



BLEED CONFIGURATION	MASS ADJUSTMENT kg
ENG ANTI-ICE ON	+1950
ENG & WING ANTI-ICE ON	+5650
A/C OFF BELOW 17000 ft	-1750

Figure 4.25 Driftdown Profiles – Net Flight Path

PRESSURE ALTITUDE 29,000 TO 31,000 ft

MAX CONTINUOUS THRUST LIMITS

BLEED CONFIGURATION	MASS ADJUSTMENT kg
ENG ANTI-ICE ON	+1950
ENG & WING ANTI-ICE ON	+5650
A/C OFF BELOW 17000 ft	-1750

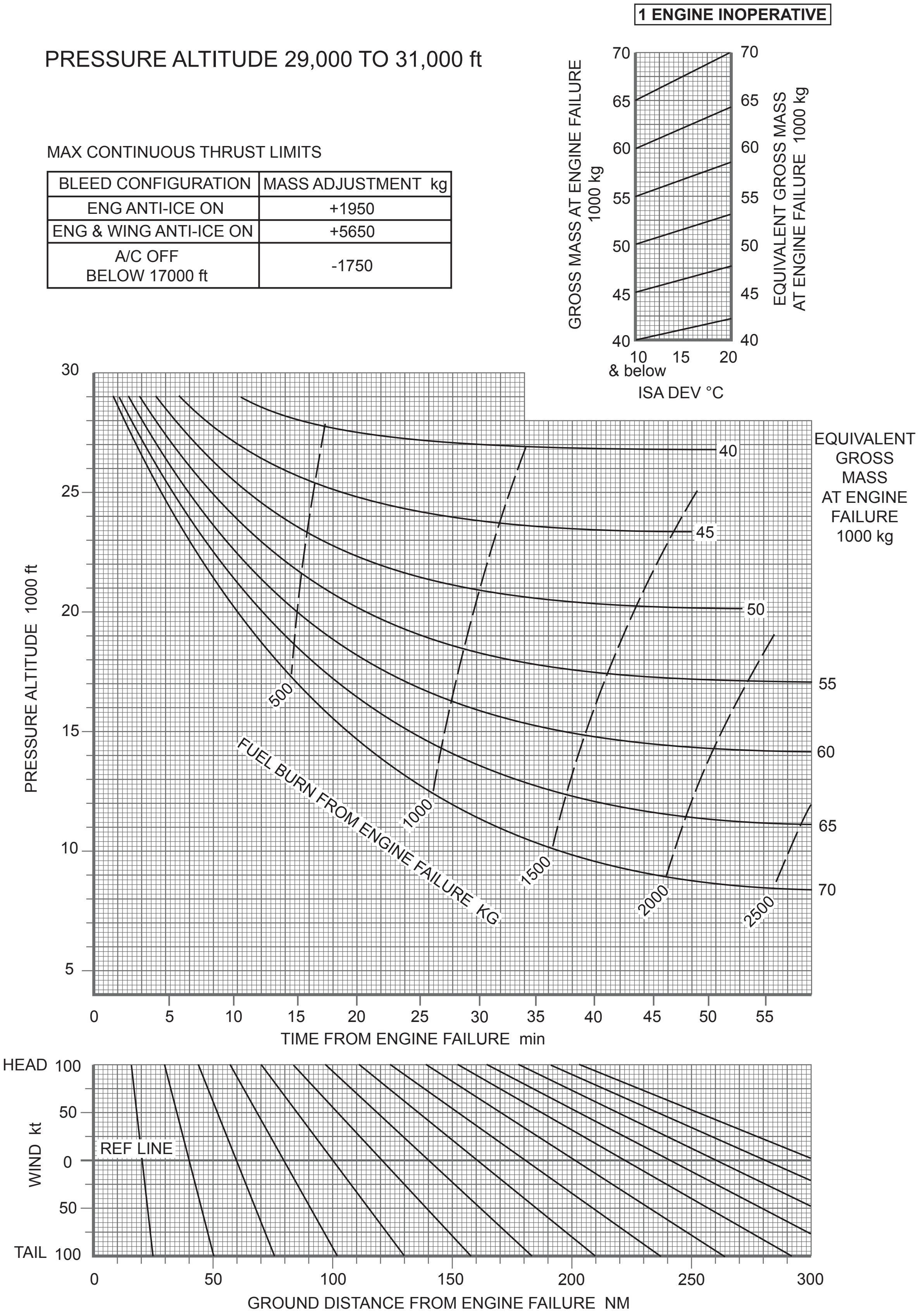
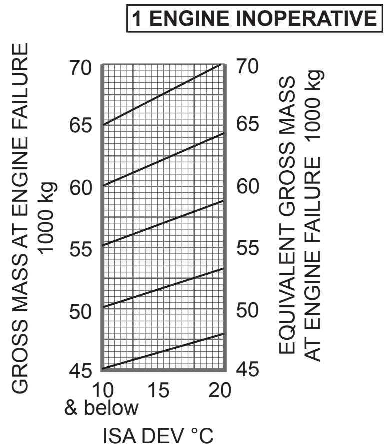


Figure 4.26 Driftdown Profiles – Net Flight Path

PRESSURE ALTITUDE 25,000 TO 27,000 ft

MAX CONTINUOUS THRUST LIMITS

BLEED CONFIGURATION	MASS ADJUSTMENT kg
ENG ANTI-ICE ON	+1950
ENG & WING ANTI-ICE ON	+5650
A/C OFF BELOW 17000 ft	-1750



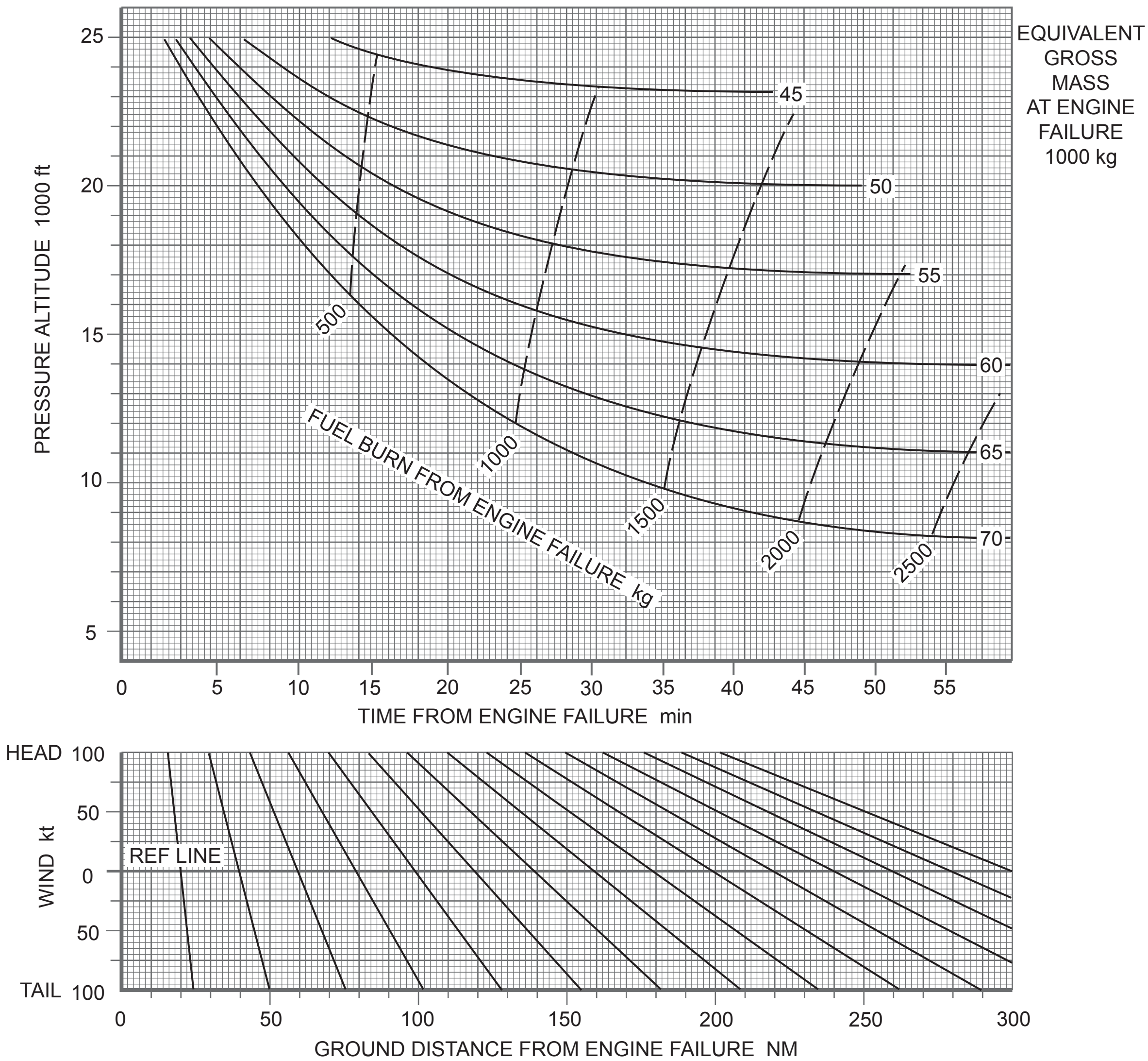


Figure 4.27 Driftdown Profiles – Net Flight Path

5 Landing

5.1 Landing Performance

The landing performance calculations are divided into two elements.

a) The field length limited landing mass can be determined from Figure 4.28.

b) The landing 'climb limit' (Figure 4.29). This mass ensures the minimum permissible gradient is obtained and should be corrected in accordance with the statements beneath the graph.

c) The maximum landing mass is the lower of a), and b) and the structural limit.

Example 1

Given:	Aerodrome Pressure Altitude	2000 ft
	Aerodrome OAT	+33 °C
	Wind Component	20 kt Head
	Runway Condition	Wet
	Flap Setting	30°
	Anti-skid System	Inoperative
	Spoilers	Automatic
	Air Conditioning	Auto
	Icing	None forecast
Solution:		
Figure 4.28:	Field length limited landing mass	46,800 kg
Figure 4.29:	Climb limited landing mass	60,400 kg
	Structural limited landing mass	54,900 kg
	Therefore Maximum Landing Mass	46,800 kg

5.2 Quick Turnaround Limit

The maximum permissible landing mass for a quick turnaround can be determined from Figure 4.30. The masses are tabulated for aerodrome pressure altitude and ambient temperature and should be adjusted in accordance with the statement below the tables for runway slope and wind component. If the landing mass exceeds this value then, after 53 minutes, check the wheel thermal plugs have not melted before commencing a take-off.

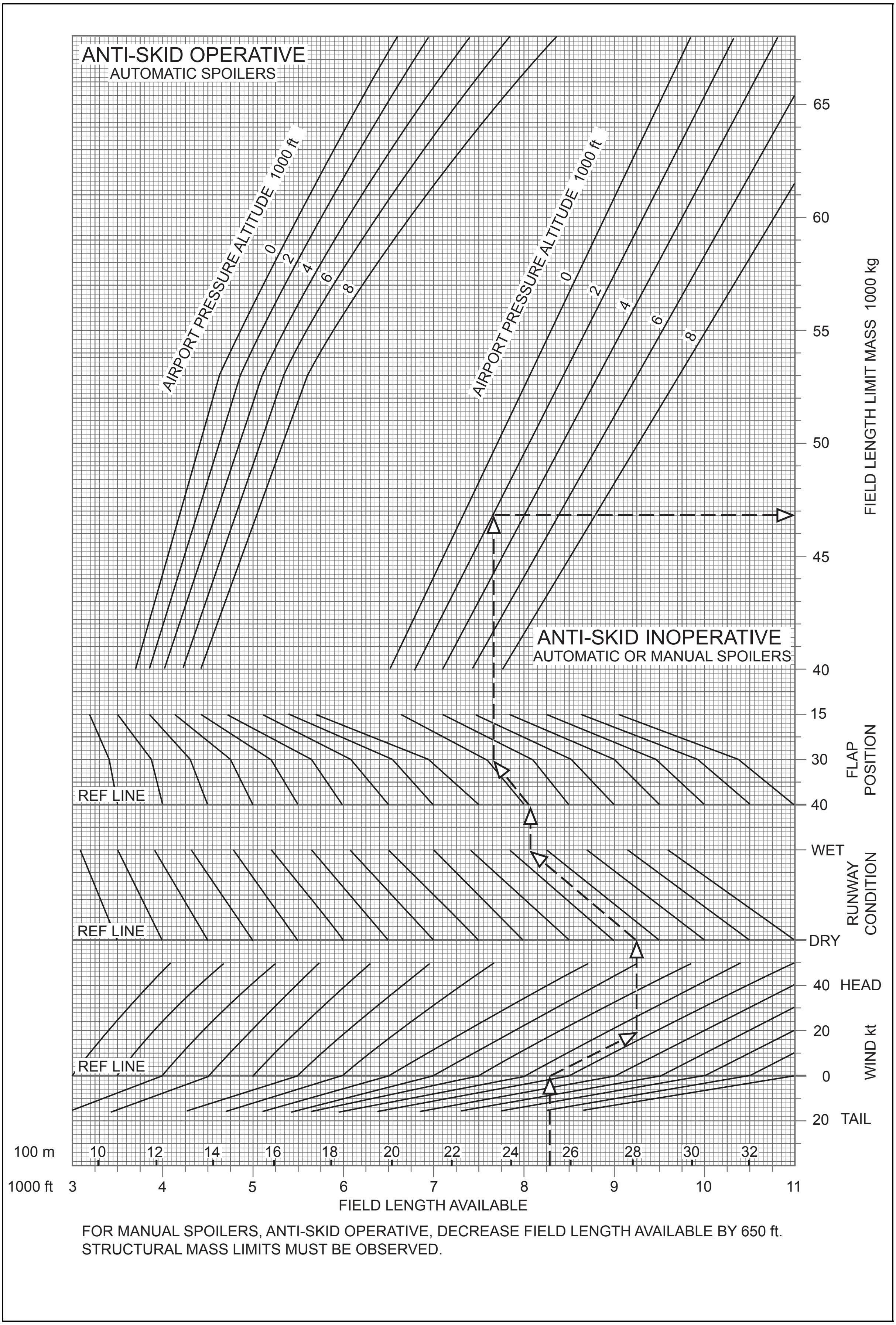
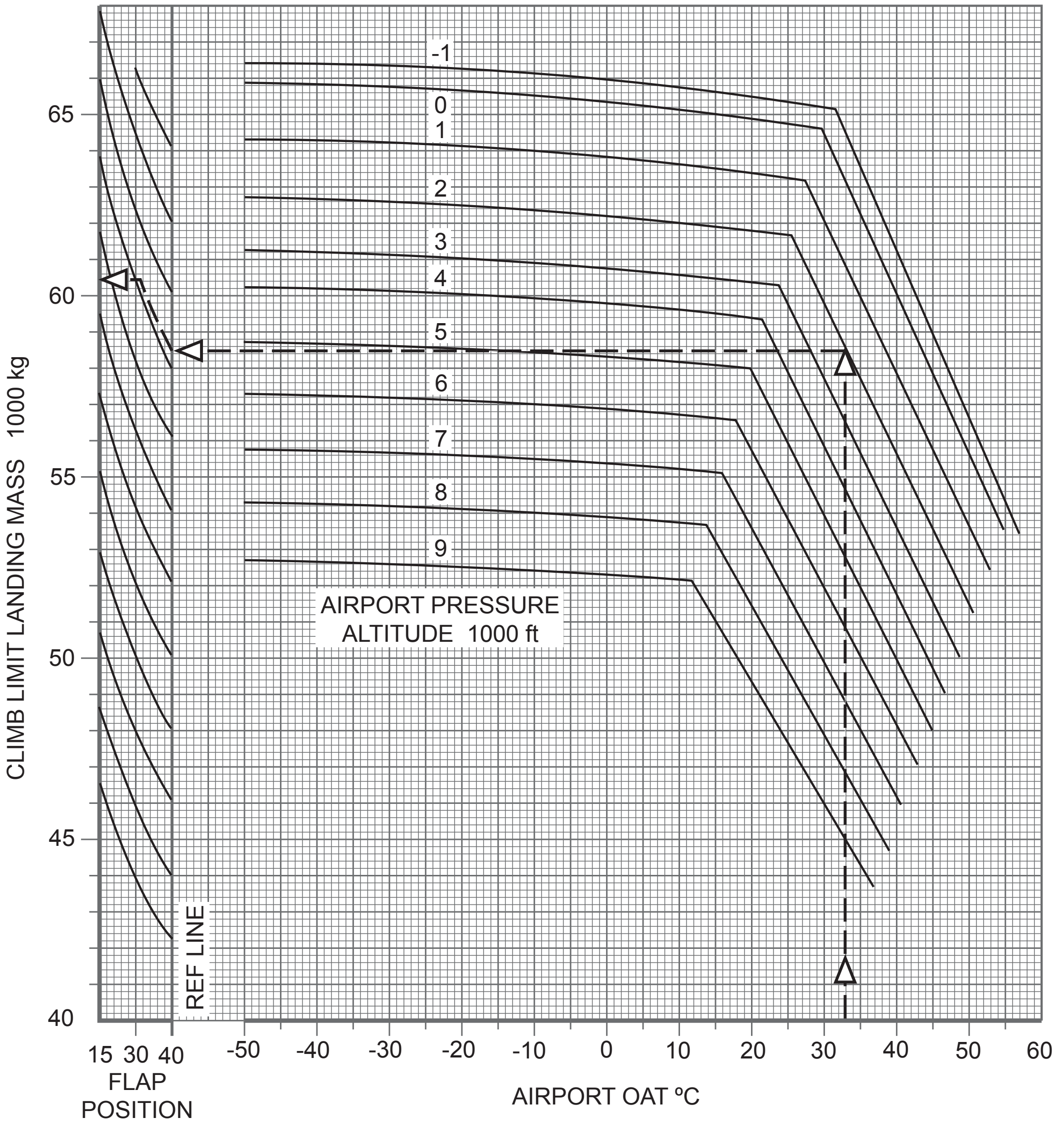


Figure 4.28 Landing Performance – Field Length Limit



BASED ON A/C AUTO. FOR PACKS OFF INCREASE:
THE FLAPS 40 ALLOWABLE MASS BY 1250 kg,
THE FLAPS 30 ALLOWABLE MASS BY 1310 kg, OR
THE FLAPS 15 ALLOWABLE MASS BY 1440 kg

IF OPERATING IN ICING CONDITIONS DURING ANY PART OF THE FLIGHT WHEN THE FORECAST LANDING TEMPERATURE IS BELOW 8ºC:
REDUCE THE FLAPS 40 CLIMB LIMIT MASS BY 4830 kg,
REDUCE THE FLAPS 30 CLIMB LIMIT MASS BY 4730 kg, OR
REDUCE THE FLAPS 15 CLIMB LIMIT MASS BY 4960 kg

FOR ANTI-ICE OPERATION, DECREASE ALLOWABLE MASS BY THE AMOUNT SHOWN IN THE TABLE BELOW

ANTI-ICE OPERATION DECREMENT kg		
FLAPS	ENGINE ONLY	ENGINE & WING
15	650	5800
30	600	5350
40	550	5250

* NOTE:
ANTI-ICE BLEED SHOULD
NOT BE USED ABOVE 10ºC

Figure 4.29 Landing Performance – Climb Limit

Figure 4.30 Quick Turnaround Limit

Flaps 15°

Aerodrome Pressure Altitude (ft)	Maximum Quick Turnaround mass (1000 kg)											
	Airport OAT											
	°F	-60	-40	-20	0	20	40	60	80	100	120	130
	°C	-51	-40	-29	-18	-7	4	16	27	38	49	54
-1000		59	57	56	54	53	52	51	50	49	49	48
0		58	56	55	54	52	51	50	49	49	48	47
1000		56	55	54	53	51	50	49	49	48	47	46
2000		55	54	53	52	50	49	49	48	47	46	
3000		54	53	52	51	49	49	48	47	46	45	
4000		54	52	51	50	49	48	47	46	45		
5000		53	51	50	49	48	47	46	45	44		
6000		51	50	49	48	47	46	45	44	44		
7000		50	49	48	47	46	45	44	44	43		
8000		49	49	47	46	45	44	44	43	42		
9000		49	48	46	45	44	44	43	42	41		

Flaps 30°

Aerodrome Pressure Altitude (ft)	Maximum Quick Turnaround mass (1000 kg)											
	Airport OAT											
	°F	-60	-40	-20	0	20	40	60	80	100	120	130
	°C	-51	-40	-29	-18	-7	4	16	27	38	49	54
-1000		66	64	62	61	59	58	57	56	55	54	54
0		64	63	61	60	59	57	56	55	54	53	53
1000		63	62	60	59	58	56	55	54	53	52	52
2000		62	60	59	58	56	55	54	53	52	51	
3000		61	59	58	57	55	54	53	52	51	50	
4000		60	58	57	55	54	53	52	51	50		
5000		59	57	56	54	54	52	51	50	49		
6000		58	56	55	54	52	51	50	49	49		
7000		56	55	54	53	51	50	49	49	48		
8000		55	54	53	51	50	49	49	48	47		
9000		54	53	52	50	49	49	48	47	46		

Flaps 40°

Aerodrome Pressure Altitude (ft)	Maximum Quick Turnaround mass (1000 kg)											
	Airport OAT											
	°F	-60	-40	-20	0	20	40	60	80	100	120	130
	°C	-51	-40	-29	-18	-7	4	16	27	38	49	54
-1000		68	67	65	64	62	60	59	58	57	56	55
0		67	65	64	62	61	59	58	57	56	55	54
1000		66	64	63	61	60	59	57	56	55	54	54
2000		64	63	61	60	59	57	56	55	54	53	
3000		64	62	60	59	58	56	55	54	53	52	
4000		62	60	59	58	56	55	54	53	52	51	
5000		61	59	58	57	55	54	53	52	51		
6000		60	58	57	55	54	53	52	51	50		
7000		59	57	56	54	53	52	51	50	49		
8000		58	56	54	54	52	51	50	49	49		
9000		56	55	54	53	51	50	49	49	48		

Add	350 kg per 1% uphill slope
Subtract	1150 kg per 1% downhill slope

Add	1100 kg per 10 kt headwind
Subtract	7450 kg per 10 kt tailwind

5.3 **Brake Cooling Schedule**

The graph at Figure 4.31 provides advisory information to enable the operator to avoid brake overheat problems. The chart enables due allowance to be made for a single stop and, by using the graph as indicated, provides advice on the procedure to be adopted and the minimum cooling time. Separate sub-graphs are provided for determining the stop distance with manual braking.

5.3.1 **Method of Use of the "Brake Cooling Schedule" Graph (Figure 4.31)**

5.3.1.1 **Abandoned Take-Off**

a) Enter the top left vertical axis at the Regulated Take-Off Mass and travel horizontally right to V_1 minus 50% of headwind or plus 150% of tailwind.

b) From this intersection, drop vertically to the first reference line then follow the gridlines to correct for Pressure Altitude and OAT.

c) From this intersection continue vertically downward to read the Brake Energy per Brake in millions of foot pounds.

d) To this value add one million foot pounds for each taxi mile to obtain the total energy.

e) From the value of the total energy continue vertically downward to determine the advised cooling schedule and recommended cooling time.

5.3.1.2 **Landing**

a) Enter the left vertical axis at the estimated landing mass and travel horizontally right to a speed of (V_{REF} - 3) kt corrected for wind component minus 50% of a headwind or plus 150% for a tailwind.

b) From this intersection, drop vertically to the first reference line then follow the gridlines to correct for Pressure Altitude and OAT.

c) From this intersection continue vertically downward to the Braking Configuration reference line.

d) Follow the grid-lines to the appropriate braking configuration.

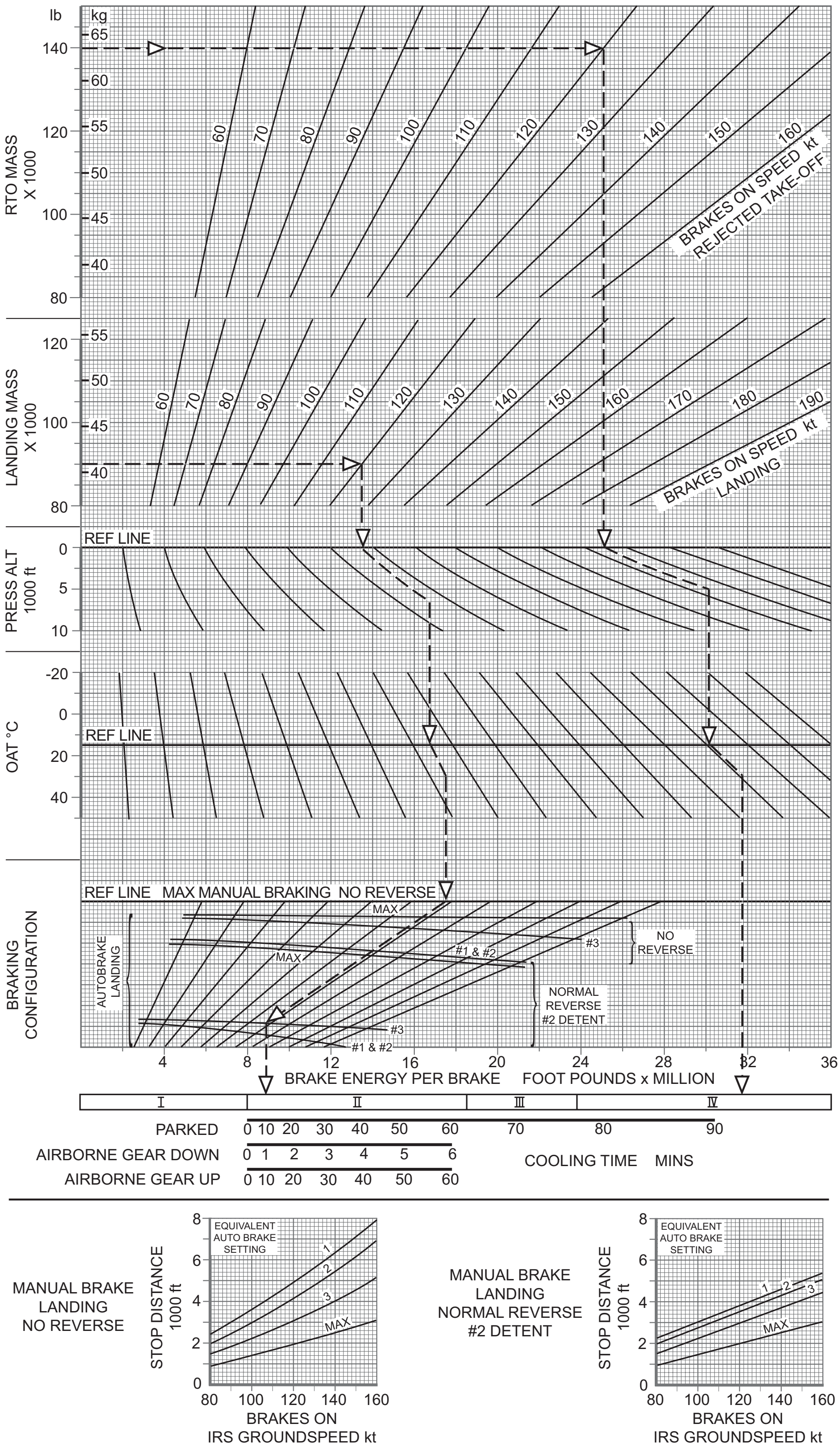
e) From the intersection continue vertically downward to read the Brake Energy per Brake in millions of foot pounds.

f) To this value, add one million foot pounds for each taxi mile to obtain the total energy.

g) From the value of the total energy on continue vertically downward to determine the advised cooling schedule and recommend cooling time.

5.3.1.3 **Braking Distance**

For a manual braked landing with no reverse thrust or for a manual braked landing with normal thrust #2 detent, select the appropriate sub-graph in Figure 4.31, then enter the sub-graph at the Brakes ON IRS Ground Speed KIAS and travel vertically up to intersect the equivalent autobrake setting. From this intersection travel horizontally left to the vertical axis to read the stopping distance in thousands of feet.



I	NORMAL	No special procedure required.
II	COOLING RECOMMENDED	Cool as scheduled. Ground cooling schedule recommended prior to take-off.
III	CAUTION	Wheel fuse plugs may melt. Delay take-off and inspect after 30 minutes. After take-off, extend gear for at least 7 minutes.
IV	FUSE PLUG MELT	No reverse thrust or braking configuration credit allowed in this area. Clear runway immediately. Do not set parking brake. Do not approach gear or attempt taxi or subsequent take-off before waiting mandatory time shown on quick turnaround limit chart. Alert fire equipment.

Figure 4.31 Brake Cooling Schedule