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DOCUMENT TITLE

AUS OPERATIONS, FLIGHT PLANNING AND PERFORMANCE

CHAPTER 12
CLIMB PERFORMANCE

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SECTION 5 - CLIMB PERFORMANCE

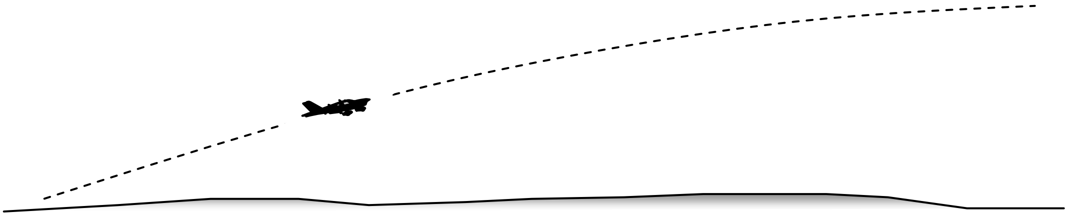
5.1 PLANNING CLIMBS

When planning climbs, assume a CRUISE-CLIMB technique. Remember from Aerodynamics that the CRUISE-CLIMB features a higher IAS than either the maximum rate or maximum angle climb speed.

5.1.1 Rate and Angle of Climb

As height increases, the density of the air decreases. This affects the climb performance in two ways:

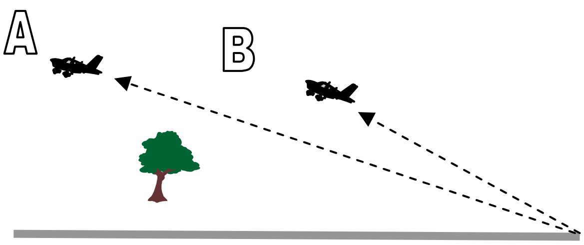
- the propeller becomes less effective due to the reduction in air density.
- the volumetric efficiency of the engine is decreased, reducing the power available.



Climb performance decreases as height increases

Both the Angle of Climb and the Rate of Climb will decay (reduce) during the climb. This may pose problems in planning factors such as:

- the climb ETI.
- the climb fuel required, *and* …
- the distance covered during the climb.



Rate of climb and angle of climb

Aircraft **'A'** has a better rate of climb. It is higher than aircraft **'B'** after the same amount of time.

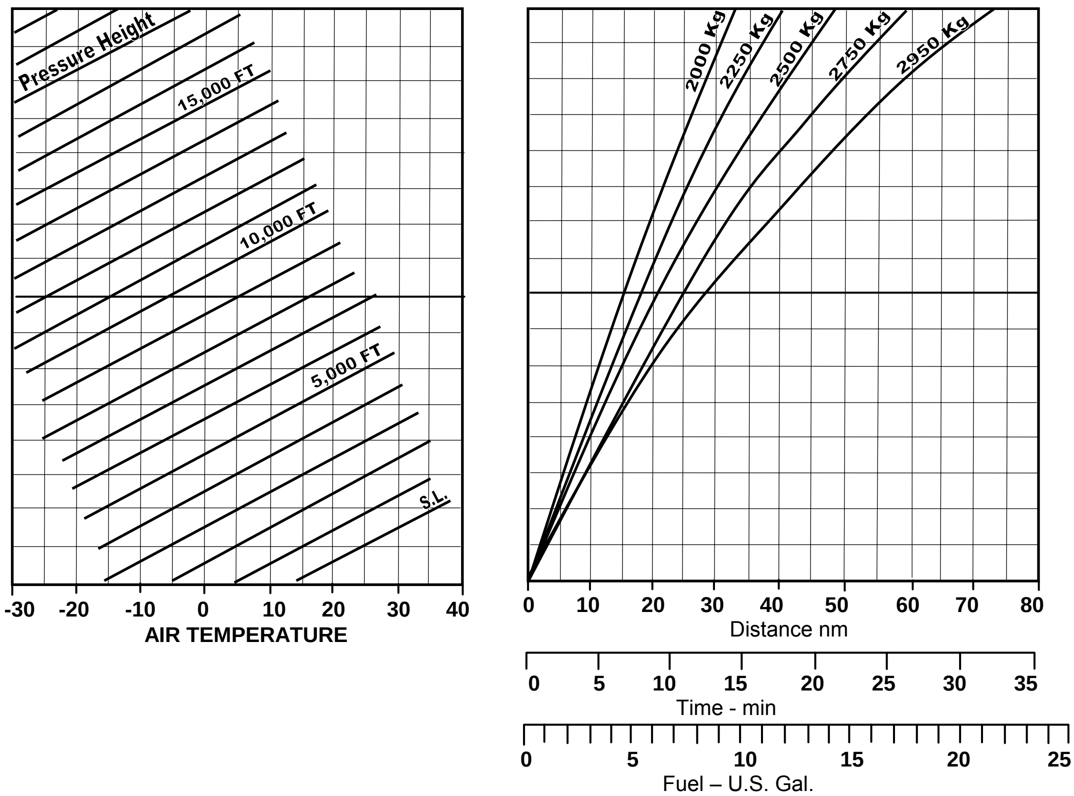
Aircraft **'B'** has achieved a better angle of climb. It would pass higher above a surface obstacle than aircraft **'A'**.

5.1.2 Graphical Representation of Cruise Climb Data

To simplify the processes of calculating accurate climb data for flight planning purposes, the ECHO Mk IV has a graph which allows us to extract ETI, fuel required and air distance covered. The climb performance depends on the DENSITY and the aircraft GROSS WEIGHT. To make it easy, the manufacturer has designed a graph which allows you to enter with PRESSURE HEIGHT and TEMPERATURE, eliminating the need to work a density height for graph entry.

Cruise – climb performance

Refer to the graph below.



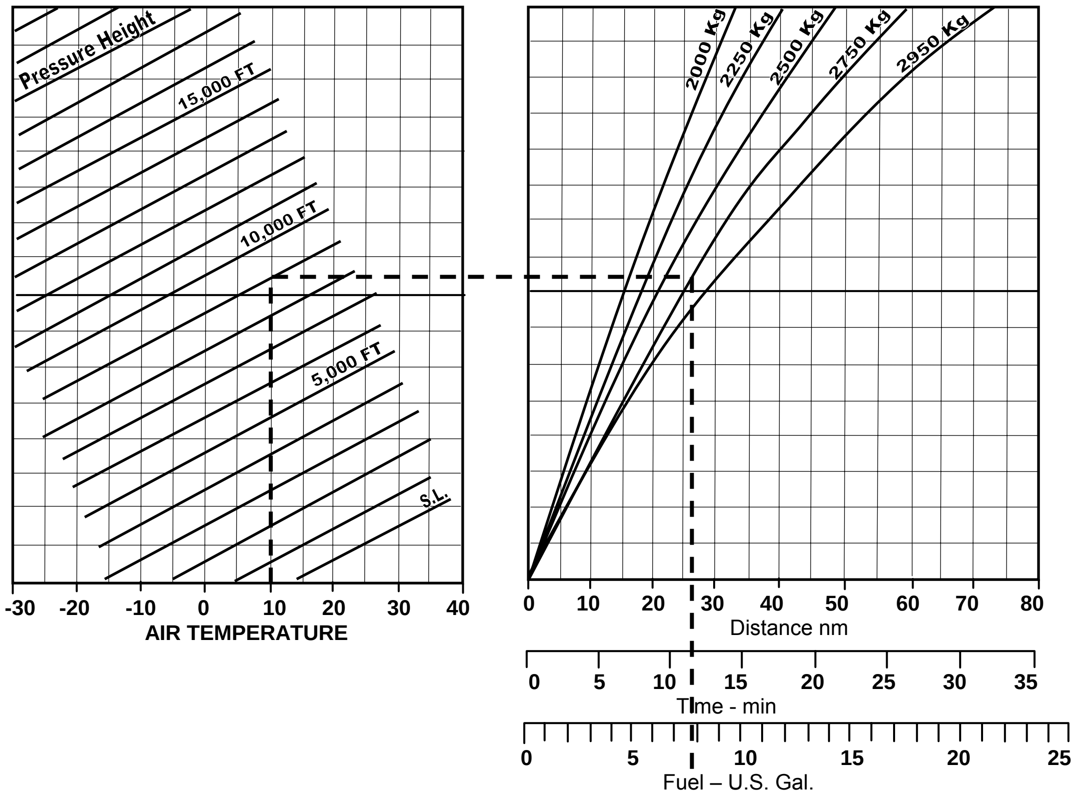
The left section of the graph allows for air density. The right section of the graph takes into account the gross weight of the aircraft at start of climb.

On the bottom of the left section of the graph, the horizontal scale is for temperature. This temperature scale represents the TRUE OUTSIDE AIR TEMPERATURE (TOAT) at TOP OF CLIMB.

In the graph you see the sloping PRESSURE HEIGHT lines representing the TOP OF CLIMB PRESSURE ALTITUDE.

The graph is based upon a climb from sea level.

Entry to the graph is on the bottom horizontal temperature scale with the estimated TOP OF CLIMB air temperature in degrees Celsius. In the example below, the top of climb temperature is + 10°C.



Example 1

Using the graph above and the information listed below, find:

- the distance to climb
- the ETI to top of climb
- the fuel used during the climb.

<u>Top of climb</u>

Pressure Height	9000 feet
Temperature	+10ºC

<u>Start of climb</u>

Pressure Height	Sea level
Temperature	+ 15ºC
Gross weight	2750 Kg

Method

a. From the entry temperature point, move vertically upwards until intersecting the sloping line which represents the TOP OF CLIMB (TOC) Pressure Height. In the example on the graph the Pressure Height is 9,000 feet.

b. From the intersection point between temperature and Pressure Height, move horizontally into the right section of the graph. This horizontal line will intercept the GROSS WEIGHT lines.

Note that the lines representing gross weight (GW) are for the gross weight at START OF CLIMB (SOC). In the case of the given example the start of climb GW is 2,750 kg.

c. From the point at which the horizontal line from the Pressure Height / temperature graph section intersects the start of climb gross weight, draw a line vertically downwards through the three scales drawn horizontally on the bottom of the right section of the graph.

The three scales represent the results. The first shows the distance covered during the climb in AIR NAUTICAL MILES (ANM), the second scale shows the climb ETI, and the third shows how much fuel will be used during the climb.

Answers

Distance to climb -	**26** ANM Climb
ETI -	**12** min
Fuel needed -	**7.7** US Gal

Example 2 - SOC at Mean Sea level

Climb from aerodrome ABC elev.	2 feet
QNH	1013.1 hPa
Surface Temp.	+15°C
TOC	FL 150
SOC Gross weight	2,850 kg
Temp. at FL 150	ISA + 10°C

Method

a. Calculate the SOC and TOC Pressure Heights.
SOC is Zero feet and TOPC is 15,000 feet Pressure Height.

b. Calculate the outside air temperature at TOC.
Temperature at S o C is +15°C.

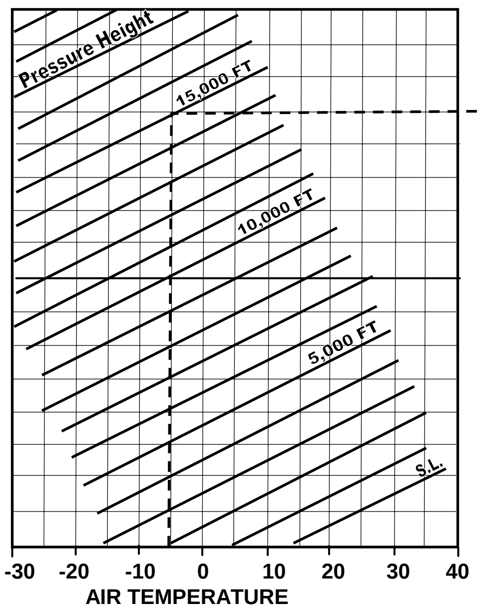
Note: TOC temperature is given as an ISA DEVIATION, this is NOT a TRUE OUTSIDE AIR TEMPERATURE (TOAT).
In ISA the temperature at FL 150 would be: 15°C - (15 x 2) = - 15°C.
The temperature is ISA + 10 and so the TOAT is -15°C + 10°C = - 5°C
Notice that the graph is designed for commencing the climb at MSL. When the SOC is higher than MSL, a different technique is used.

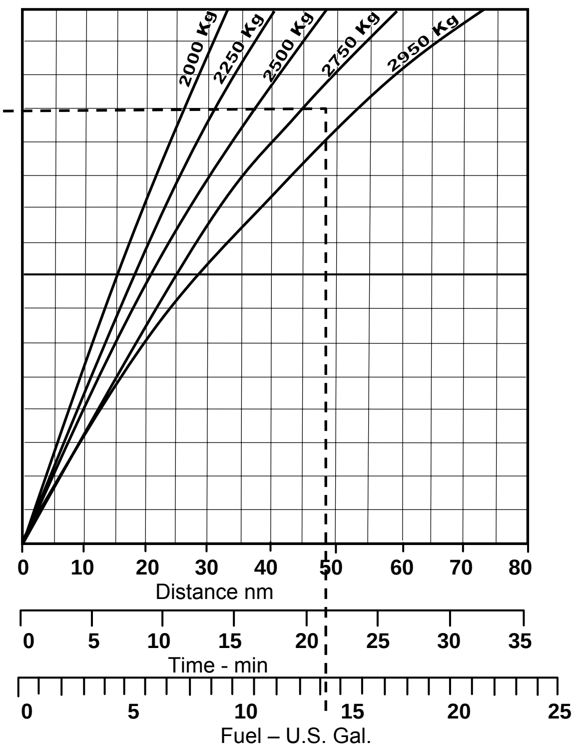
c. Interpolate the TOC TOAT (- 5ºC) on the left bottom scale and draw a vertical line upwards.

d. From the intersection between this vertical line and the line representing a Pressure Height of 15,000 feet draw a horizontal line into the right section of the graph in which you intercept the GW lines.

e. From the intersection between the horizontal line and the line representing the start of climb GW of 2,850 kg, draw a vertical line downwards through the horizontal scales on the bottom of the right side of the graph.

f. Read the results from the horizontal scales.





Answers

Distance to TOC from sea level- **48 nm**
Time to climb from SL - **21.5 minutes**
Fuel used - **14.2** US gallons

Example 3 - SOC higher than MSL

Usually a climb is commenced from an aerodrome which is not exactly at MSL. You are given the following information:

Start of Climb	5,000 feet	TOC	FL 160
Local QNH	1013 hPa	TOC Temp	- 10°C
Surface Temp	+ 20°C	SOC GW	2,950 kg

The rate of climb decays at a non linear rate with increasing height. For this reason the vertical difference between start of climb and top of climb cannot be used as vertical displacement starting from MSL in the graph.

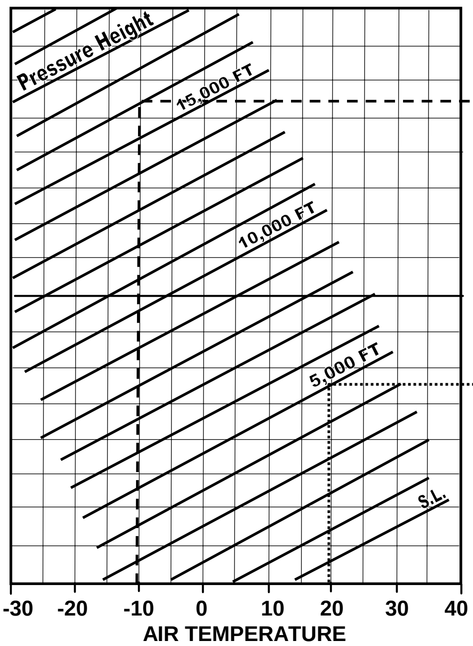
The climb STARTS at 5,000 feet. The graph assumes that a climb always starts from MSL. When climbing from 5,000 feet to FL160 there is a saving of the time, distance and fuel that would be used to climb from MSL to 5,000 feet.

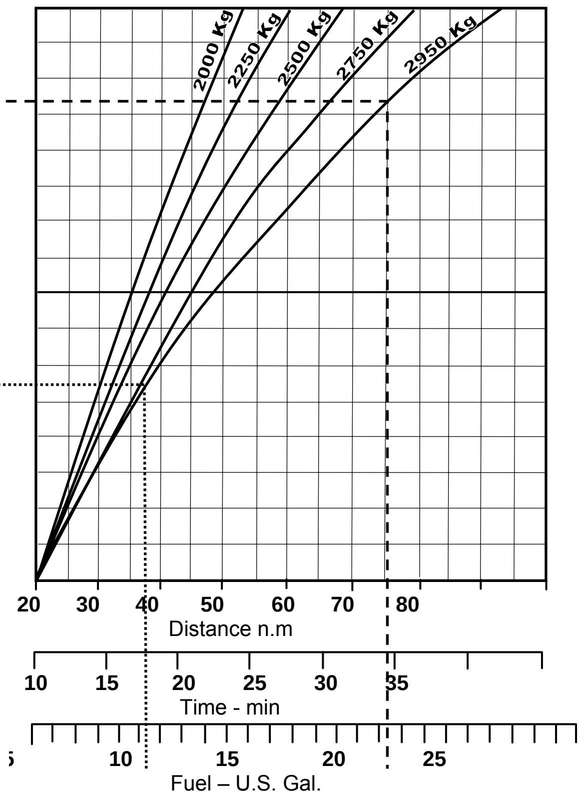
a. Calculate the time, fuel and distance it takes to climb from MSL to FL160.

b. Calculate the time, fuel and distance it takes to climb from SL to 5,000 feet.

c. Subtract the time, fuel and distance for MSL to 5,000 feet from the figures for the climb from MSL to FL160. The difference indicates the actual time, fuel and distance used on climb from 5,000 feet to FL160.

MSL to FL160	56 NM	24 min	16.5 Gal
- MSL to 5.000 ft	18 ANM	8 min	5.5 Gal
5,000 ft to FL 160	38 ANM	16 min	11.0 Gal.





Answers - 5,000 ft to FL 160:
38 ANM **16 min** **11 Gal**

Example 4 - SOC higher than MSL

Given the following information, calculate the ETI, fuel and distance to climb.

SOC GW	2,750 kg
Airfield elevation	2,000 feet
Surface Temp	+25°C
Local QNH	1001 hPa
TOC	FL 130
TOAT	ISA + 15°C
Area QNH	995 hPa

a. Calculate the SOC Pressure Height:

PH = 1013 hPa - 1001hPa = 12 hPa × 30 = 360 feet

2,000 ft + 360 ft = 2,360 ft

b. Calculate TOC Pressure Height:

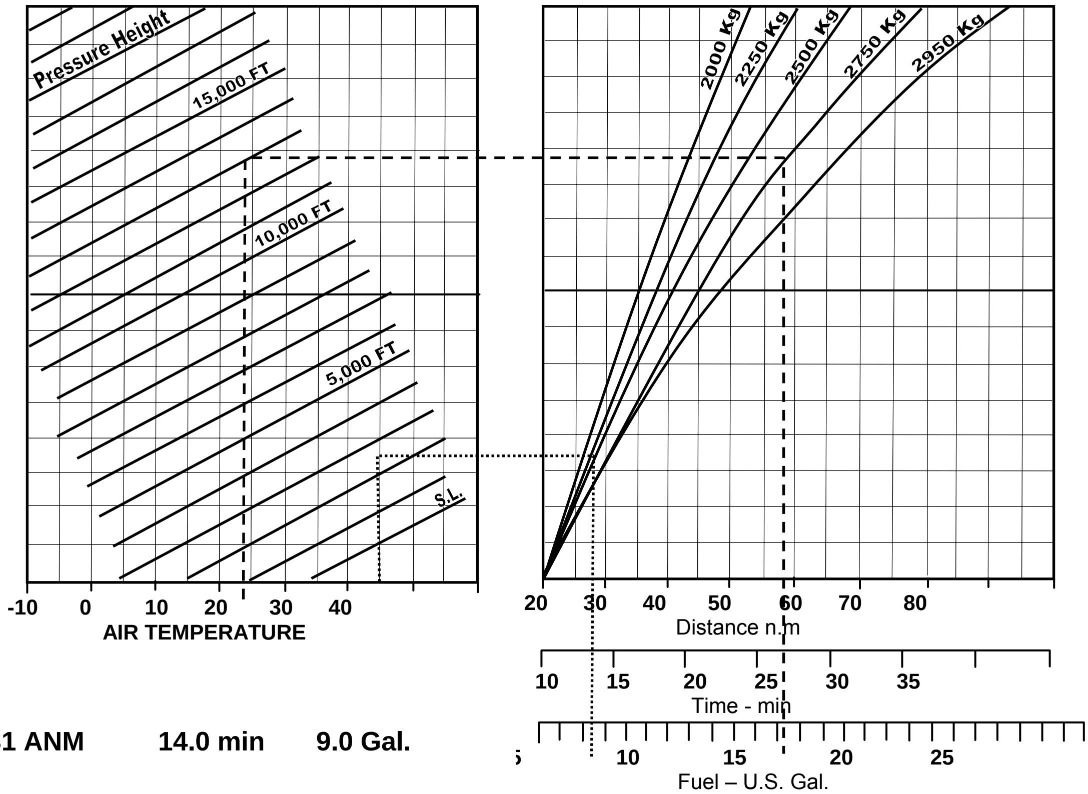
PH = 13,000 ft (FL 130).

ISA temperature at FL 130 = 15°C - (13 x 2) = - 11°C.

It is ISA + 15, TOAT = - 11 + 15 = + 4°C.

c. Obtain the following climb data from the graph.

MSL to FL 130:	38 ANM	17.0 min	11.5 Gal
- MSL to 2,360 ft:	8 ANM	3.0 min	2.5 Gal
5.000 ft to FL 160:	30 ANM	14.0 min	9.0 Gal.



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31 ANM 14.0 min 9.0 Gal.

5.1.3 Wind Effect

Climb distance is given in AIR NAUTICAL MILES (ANM) instead of GROUND NAUTICAL MILES (GNM). The distances extracted from the graph do not take the wind component into account.
A WIND VELOCITY (W/V) of 250/40 means that the wind is coming from 250 degrees at a speed of 40 nautical miles per hour (knots). The air itself is moving at 40 knots from the south west.
If the air moves 40 nm in 60 minutes, it will move 20 nm in 30 minutes and 10 nm in 15 minutes.
To calculate the WIND EFFECT (W/E), use the time to climb applied to the wind speed to calculate the distance the air has moved across the ground during the climb.
W/V 250/40 - how far does the mass of air travel in 24 minutes?

Speed x Time = Distance

$$\frac{40 \text{ kt} \times 24 \text{ minutes}}{60} = 16 \text{ NM}$$

In 24 minutes the air will travel 16 NM.

5.1.4 Calculate Climb Ground Nautical Miles

Climb ground nautical miles is obtained by correcting air nautical miles (found from the graph) for wind effect. The effect of a tailwind component is added and the effect of a headwind component is subtracted.

Example 1
On climb the aircraft covers 30 air nautical miles in 20 minutes and is subjected to a tailwind of 15 kt. How many GNM would the aircraft cover during the climb?

a. Calculate the wind effect (W/E) during the climb.
A tailwind component of 15 kt for 20 minutes = 15 / 60 $\times$ 20
= 5 nautical miles.

b. During the climb the effect of a tailwind is to move the aircraft further along track by a distance of 5 miles.

Add or subtract the wind effect, depending on whether there is a tailwind or a headwind.
In this problem there is a tailwind, so the wind effect needs to be added.
The ground nautical miles = 30 ANM + 5 NM = 35 nm

Answer - **35** ground nautical miles.

c. In the same problem if there was a headwind of 15 kt, it would be necessary to SUBTRACT the wind effect from the air distance.
The ground nautical miles would be = 30 ANM - 5 nm W/E

Answer - **25** ground nautical miles.
Example 2 Given the following information, calculate the ground miles covered.

Climb ETI	18 minutes
Climb W/C	30 kt HWC
Climb distance	20 ANM

a. Calculate the wind effect:

W/E = (- 30 kt x 18 min) / 60

= - 9 nm

b. Subtract the wind effect (headwind):

20 ANM - 9 nm W/E

= 11 GNM

Answer - 11 nm

Example 3

Given the following information, calculate the ground miles covered.

Climb ETI	26 min
Climb W/C	25 kt TWC
Climb distance	34 ANM

a. Calculate the wind effect:

W/E = (+ 25 kt x 26 min) / 60

= 10.83

b. Add the Wind effect (tailwind)

34 ANM +10.83 NM W/E

Answer - 44.83 GNM

5.2 VERTICAL DISPLACEMENT

Vertical displacement is the height difference between the start of climb and the top of climb.

Up to 10,000 feet, height is measured as an ALTITUDE. This height is AMSL and it uses QNH as the datum.

Above 10,000 feet, height is measured as a FLIGHT LEVEL. Flight levels are expressions of Pressure Height and so use 1013 hPa level as the datum.

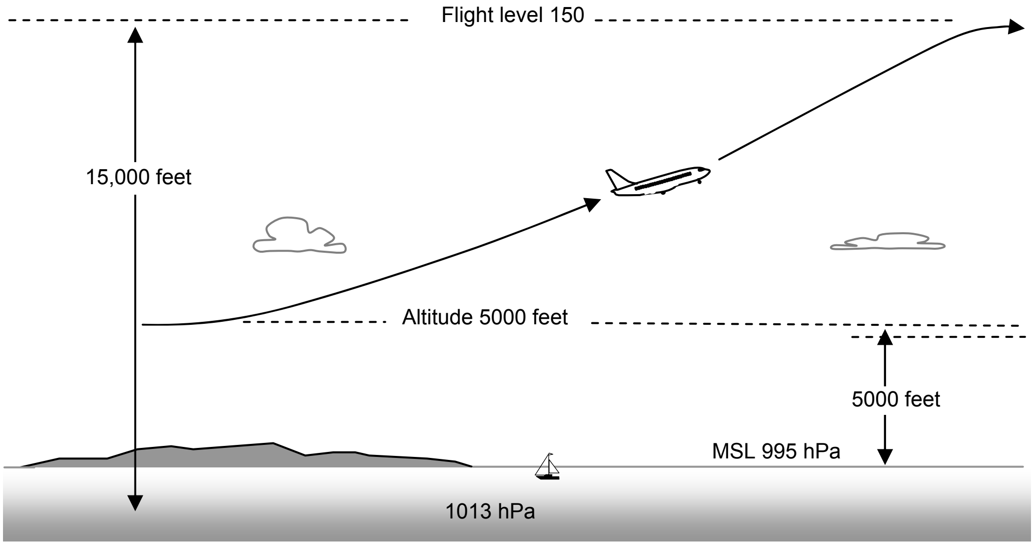
5.2.1 Vertical Displacement based on Pressure Heights

If the QNH is 1013 hPa (which does not happen very often) then the altitude and Pressure Height are both the same. However, should the QNH differ from ISA, the altitude will need to be converted to a Pressure Height before calculating vertical displacement.

Example 1 Refer to the diagram below.

Given the following information, calculate the vertical displacement.

SOC	A 050
TOC	FL 150
Area QNH	995 hPa



As the SOC is measured as height AMSL but the TOC is measured as a height above 1013 hPa, the vertical displacement cannot be measured without using a common datum.

It is usual to convert both heights into PRESSURE HEIGHTS.

Calculation

a. Convert ALT 5,000 feet into a PH:

1013 hPa - 995 hPa = 18 hPa x 30 ft / hPa = 540 ft.

5,000 ft + 540 ft = 5,540 ft

b. Calculate the Vertical Displacement. Subtract one Pressure Height from the other.

PH 15,000 ft - PH 5,540 ft = 9,460 ft Vertical Displacement

Answer - 9,460 ft

Example 2

An aircraft has taken off from an aerodrome having an elevation of 3,000 feet. When at 500 feet AGL a clearance to climb to FL120 is received. The area QNH is 1023 hPa. Calculate the vertical displacement.

Calculation

a. Convert both SOC and TOC into a PH. The SOC is given as a height AGL.

b. Convert height AGL into an altitude:
Elev 3,000 feet + Height AGL 500 feet = altitude 3,500 feet.

c. Convert the altitude to a Pressure Height:
1013 hPa - 1023 hPa = - 10 hPa x 30 ft/hPa = - 300 ft.
3,500 ft - 300 ft = PH 3,200 ft

d. Calculate the PH at TOC:
FL 120 = PH 12,000 ft.

e. Calculate the vertical displacement:
PH 12,000 ft - PH 3,200 ft = vertical displacement 8,800 ft

Answer - 8,800 ft

5.2.2 Vertical Displacement based on Density Heights

Aircraft performance is dependent on Density Height. When required to calculate a vertical displacement for the purpose of calculating a climb ETI, the vertical displacement may be based on DENSITY HEIGHT.

Example

Given the following information, calculate the vertical displacement as a change of Density Height.

SOC	500 ft AGL
Aerodrome Elev.	2,000 ft
QNH	1003 hPa
Surface Temp.	+ 20°C
TOC	FL 150
Temp. at FL 150	- 10°C

Calculation

a. Calculate SOC as height AGL:

Elev. 2,000 ft + 500 ft AGL = 2,500 ft altitude

b. Calculate the SOC as a Density Height:

hPa variation from ISA = 1013 hPa - 1003 hPa

= 10 hPa x 30 ft / hPa = 300 ft

c. Calculate SOC as a Pressure Height:

PH = 2500 ft + 300 ft = 2800 ft

d. Calculate the ISA deviation:

ISA temp at 2,800 ft = + 15°C - (3 x 2)

= + 9°C

Temp at surface = + 20°C

Temp drops 2°C / 1000 ft = 1°C / 500 ft

Temperature at SOC 500 ft AGL = + 20 – 1 = + 19°C

ISA deviation = ISA + 10

e. Calculate the Density Height at SOC:

DH = PH + (ISA deviation x 120)

= 2,800 ft + (+ 10 x 120) = 2,800 + 1,200

= 4,000 ft

f. Calculate the Density Height at TOC:

PH = 15,000 ft

ISA temp at FL 150 = + 15°C - (15 x 2)

= - 15°C

Actual temperature = - 10°C

ISA Deviation = ISA + 5

DH = PH + (ISA deviation x 120)

= 15,000 ft + (+ 5 x 120)

= 15,000 + 600 ft

= 15,600 ft

g. Now calculate the vertical displacement. Subtract the DH at SOC from the Density Height at TOC.

TOC	15,600 ft
- SOC	4,000 ft
V displ.	11,600 ft

Answer - 11,600 ft

5.3 RATES OF CLIMB

5.3.1 Calculating the Rate of Climb

As the Rate of Climb (ROC) decays with increasing height, it is necessary to calculate an average ROC.
To account for the decay in ROC during the climb, use an average ROC at ⅔ of the vertical displacement. This assumes that as much time will be spent climbing for the last third as the time spent for the first ⅔.

Example 1
Consider a climb with a vertical displacement of 6,000 feet.

a. Calculate ⅔ of 6,000 feet:

⅔ x 6,000 = 4,000 ft

b. Calculate the loss in climb performance:
It can also be assumed that the ROC also decays linearly. If the SOC ROC is 1,000 ft / min and the TOC ROC is expected to be 700 ft / min, the loss in performance is calculated as follows:

SOC	1,000 ft / min
- TOC	700 ft / min
Loss	300 ft / min

c. Calculate the average rate of climb:
Assume that at ⅔ of the vertical displacement, there has been a loss of ⅔ in the ROC. In this example, ⅔ of 300 feet / min equals 200 ft / min

SOC	1,000 ft / min
- Loss	200 ft / min
Average ROC	800 ft / min

Answer - 800 ft/min

Example 2
Given the following information, calculate the average ROC.

SOC	1050 ft / min ROC.
TOC	600 ft / min ROC.

Calculation -

a. Calculate the total loss between the SOC and the TOC

1050 ft / min - 600 ft / min = 450 ft / min

b. Calculate the loss at ⅔ vertical displacement:

450 x ⅔ = 300 ft / min

c. Calculate the average ROC by subtracting the loss at ⅔ vertical displacement from the INITIAL ROC:

1050 ft / min - 300 ft / min = 750 ft / min

Answer - **750 ft / min**

5.3.2 Calculating Climb ETI

To calculate the climb ETI, divide the vertical displacement by the average ROC.

Example - Given the following information, calculate the climb ETI.

Vertical displacement	3,000 ft
Average ROC	600 ft / min

Calculation -

$$\frac{3{,}000 \text{ ft}}{600 \text{ ft / min}} = 5 \text{ min}$$

Answer - **5 minutes**

5.3.3 Using Tabulated Climb Data (Two Engines)

Refer to the ECHO Mk IV Maximum Climb Performance table (Two Engines), which is reproduced on the next page.

The chart gives the ROC at any given PRESSURE HEIGHT and GROSS WEIGHT in the STANDARD ATMOSPHERE. If there is an ISA Deviation it is necessary to make adjustments.

An altitude or FL in a Standard Atmosphere is a Density Height. To use the chart below, convert all altitudes or Flight Levels into Density Heights.

MAXIMUM CLIMB PERFORMANCE (TWO ENGINES)

Pressure Height (feet)	Gross weight					
	2950 Kg		2500 Kg		2000 Kg	
	TAS (Kt)	ROC (fpm)	TAS (Kt)	ROC (fpm)	TAS (Kt)	ROC (fpm)
Zero	101	1600	92	2250	82	2950
5,000	109	1500	99	2100	88	2800
10,000	118	1400	107	1950	95	2650
15,000	128	1300	116	1800	104	2500
20,000	139	800	126	1250	112	1800

Enter the table in the Pressure Height column with the DENSITY HEIGHT. Interpolate to calculate the values for the height applicable.
The table shows the ROC obtainable when climbing at that height. This ROC from the table is valid ONLY for the height at which the table was entered.

Example

Given the following information, calculate the maximum rate of climb at 4,000 feet.

Altitude	4,000 ft
QNH	1013 hPa
TOAT	+7°C
GW	2,500 kg

Method

a. Calculate the density height at 4,000 feet.
The QNH and temperature are standard and so the Density Height is 4,000 feet.

b. Determine between which tabulated values the DH 4,000 ft is found:
4,000 ft is between ZERO ft and 5,000 ft.

c. Calculate the ROC loss from ZERO to 5,000 ft:

ROC at ZERO feet at 2,500 kg	=	2,250 ft / min
- ROC at 5,000 ft at 2,500 kg	=	2,100 ft / min
ROC Loss	=	150 ft / min

d. The difference between ZERO ft and 5,000 ft is 5,000 ft.
A loss of 150 ft / min occurs while gaining 5,000 ft.
Calculate how many ft / min is lost when climbing 1000 ft, then multiply the result by 4:

$$\frac{150 \text{ ft / min}}{5} \times 4 = 120 \text{ ft / min}$$

e. Subtract the loss of 120 ft / min from the ZERO ft ROC:
2,250 ft / min - 120 ft / min = 2,130 ft / min

The ROC at 4,000 ft at 2,500 kg is 2,130 ft / min

Answer - The maximum ROC at 4,000 feet is 2,130 fpm.

5.3.4 Using Tabulated Climb Data (One Engine)

The table for a single engine climb (One Engine) works in exactly the same manner.

MAXIMUM CLIMB PERFORMANCE (ONE ENGINE)

Pressure Height (feet)	Gross weight					
	2950 Kg		2500 Kg		2000 Kg	
	TAS (Kt)	ROC (fpm)	TAS (Kt)	ROC (fpm)	TAS (Kt)	ROC (fpm)
Zero	105	280	97	525	92	780
5,000	112	200	103	450	98	700
10,000	120	100	111	360	106	625
15,000	129	20	119	270	115	530

Example

Given the following information, calculate the maximum single engine rate of climb at 3,000 feet (A030).

GW	2,500 kg
Altitude	3,000 ft
QNH	1003 hPa
TOAT	+15°C

a. Calculate the Pressure Height at A030:

hPa variation from ISA = 1013 hPa - 1003 hPa
= 10 hPa x 30 ft / hPa
= 300 ft
PH = 3,000 ft + 300 ft = 3,300 ft

b. Calculate the Density Height:

ISA temperature at 3,300 ft PH = + 15°C - (3.5 x 2) = + 8°C
Actual temp. = + 15°C
Deviation = ISA + 7
DH = 3,300 ft + (+ 7 x 120)
= 3,300 + 840
DH = 4,140 ft

c. Calculate position of DH 4,140 ft between tabulated values:

ZERO	525 ft / min
5,000	450 ft / min
LOSS	75 ft / min

d. Calculate the performance loss to 4,140 ft:

(75 ft / min / 5,000 ft) x 4,140 = 62 ft / min

d. Subtract the loss from the ROC at the LOWER height:

at ZERO ROC = 525 ft / min
- 62 ft / min
at 4,140 ft ROC = 463 ft / min

5.3.4 Climbing after an engine failure in a twin-engine aircraft

Assume a take off with an Echo Mk IV from a given aerodrome. Refer to the diagram on the next page.

Example 1 You are given the following information:

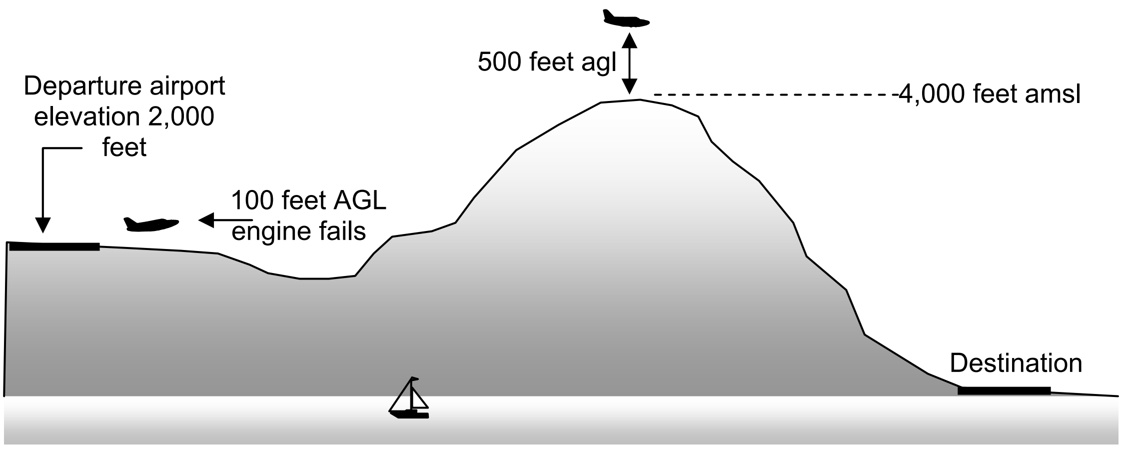
Aerodrome Elevation	2,000 ft
Local QNH	1012.7 hPa
Surface temperature	+ 30°C
Area QNH	1013.2 hPa

At 100 feet AGL, the left engine fails. The departure aerodrome is unavailable for a landing.
It is now necessary to fly over a mountain peak with an elevation of 4,000 feet to get to the nearest alternate aerodrome. The gross weight was 2,500 kg when the engine failed.

You are asked to calculate the:

a. the ROC following the failure of one engine *and ….*

b. the ETI to the minimum altitude to overfly the mountain peak.



Calculation
To solve this problem you need to:

- Calculate the density height at SOC.
- Calculate the vertical displacement.
- Calculate ⅔ of the vertical displacement.

To calculate vertical displacement, we need to determine the TOC. There is a legal requirement to clear terrain by 500 feet and to clear a 4,000 foot mountain will require a climb to 4,500 feet.

a. Calculate the density height at SOC:

The engine failed 100 ft AGL. The aerodrome is 2,000 feet high. The engine has failed at an altitude of:

2000 ft + 100 ft = 2,100 ft

The QNH is 1012.7 which is almost 1013. SOC Pressure Height is 2,100 ft.

At 2,100 ft PH the ISA temperature is:

+ 15°C - (2 x 2) = 11°C

The actual temperature is + 30°C which is a deviation of ISA + 19

DH = 2,100 ft + (+19 x 120) = 4,380 ft

- **The density height at SOC is 4,380 ft**

b. Calculate the vertical displacement.

Calculate the TOC density height:

As the area QNH is 1013.2, the TOC is at a PH of 4,500 ft. An actual TOAT at 4,500 ft is not given and so the deviation of ISA = 19 is assumed.

DH = 4,5OO ft + (+19 x 120) = 6,780 ft

Calculate ⅔ of the Vertical Displacement:

TOC DH	6,780 ft
- SOC DH	4.380ft
Vertical Displacement	2,400 ft

The vertical displacement is 2,400 ft.

⅔ vertical displacement = 2,400 x ⅔ = 1,600 ft.

Question 'a.' asks for the initial ROC which is the rate to which the ROC will decay when the engine fails.

The single engine climb performance chart below from the Echo Mk IV Manual gives the answer.

MAXIMUM CLIMB PERFORMANCE (ONE ENGINE)

Pressure Height (feet)	Gross weight					
	2950 Kg		2500 Kg		2000 Kg	
	TAS (Kt)	ROC (fpm)	TAS (Kt)	ROC (fpm)	TAS (Kt)	ROC (fpm)
Zero	105	280	97	525	92	780
5,000	112	200	103	450	98	700
10,000	120	100	111	360	106	625
15,000	129	20	119	270	115	530

ROC at ZERO ft at 2,500 kg = 525 ft / min
- ROC at 5,000 ft at 2,500 kg = 450 ft / min
Loss from 0 ft to 5,000 ft = 75 ft / min

The loss from 0 ft to 4,380 ft would be:

75 ft / min / 5,000 ft x 4,380 ft = 66ft / min

At the SOC DH the ROC would be:

ZERO ft ROC 525 ft / min
- Loss to 4,380 ft 66 ft / min
ROC at 4,380 ft 459 ft / min

Answer - a. **459 fpm**

Now calculate the Density Height at ⅔ of the vertical displacement:

SOC DH 4,380 ft
+ ⅔ vertical displacement. 1,600 ft
⅔ DH 5,980 ft

Using the chart on the previous page, the ROC at ⅔ of the vertical displacement can then be taken as an average ROC:

5,000 ft at 2,500 kg 450 ft / min
- 10,000 ft at 2,500 kg 360 ft / min
Loss 5,000 ft - 10,000 ft 90 ft / min

This would mean a loss from 5,000 ft to 5,980 ft (980 ft) of:

(90 ft/min / 5,000 ft) x (5,980 ft - 5,000 ft) = 18 ft / min

The average ROC would be:

ROC at 5,000 ft DH 450 ft / min
- Loss 18 ft / min
ROC at 5,980 ft 432 ft / min

The aircraft is climbing through a Vertical Displacement of 2,400 ft. The ETI to height would be:

$$\frac{2{,}400 \text{ ft}}{432 \text{ ft / min}} = 5.55 \text{ min or } 5 \text{ min } 33 \text{ secs.}$$

Answer b ETI to min altitude to overfly the mountain peak is **5.55 minutes or 5 minutes 33 seconds.**

Example 2 You are given the following information:

Aerodrome Elev.	3,500 ft
QNH	1000 hPa
Surface Temp	+20°C
Gross Weight	2,950 kg

When 50 ft AGL, the starboard engine fails. You are asked to calculate:

a. The initial ROC that could be expected.

b. The ETI to the minimum altitude to overfly the mountain peak.

Calculation

a. Calculate start of climb altitude:

SOC Altitude = 3,500 ft + 50 ft = 3,550 ft

b. Calculate SOC Pressure Height:

PH = 1013 - 1000 = 13 x 30

= 390 ft variation from ISA

= 3,550 ft + 390 ft = 3,940 ft

c. Calculate SOC Density Height:

ISA temperature at 3,940 ft = +15 - (4 x 2) = + 7

Actual temperature = +20

= ISA + 13

DH = 3,940 + (+13 x 120) = 5,500 feet

d. Calculate TOC Density Height:

Circuit height is 1,000 ft AGL, which is

3,500 ft + 1,000 ft = 4,500 ft altitude.

1013 hPa is 390 ft below MSL.

PH = 4, 500 ft + 390 ft = 4,890 ft

TOC DH = 4,890 + (13 x 120) = 6,450 feet

e. Calculate vertical displacement:

6,450 ft - 5,500 ft = 950 ft

950 ft x ⅔ = 633 ft

f. Calculate ⅔ Vertical Displacement DH:

5,500 ft + 633ft = 6,133 ft

g. Calculate initial ROC:

ROC at 5,000 ft GW 2,950 kg	200 ft / min
ROC at 10,000 ft GW 2,950 kg	100 ft / min
Loss in 5,000 ft	100 ft / min

Initial climb is 5,500 ft - 5,000 ft = 500 ft above 5,000 ft.

Loss to 5,500 ft DH = $\frac{100 \text{ ft / min}}{5{,}000 \text{ ft}}$ x 500 ft = 10 ft / min

ROC at 5,000 ft	200 ft / min
- Loss to 5,500 ft	10 ft / min
Initial ROC	190 ft / min

h. Calculate average ROC:

⅔ DH is 6,133 ft which is 6,133 - 5,000 = 1,133 ft higher than the tabulated 5,000 ft DH.

ROC loss to 6,133 ft = (100 ft / min / 5,000 ft) x 1,133 ft.

= 23 ft / min

ROC at 5,000 ft	200 ft / min
- Loss to 6,013 ft	23 ft / min
Average ROC	177 ft / min

i. Calculate climb ETI:

Vertical displacement = 950 ft / Average ROC 177 ft / min = 5.37 min

Answers -

a. **Initial ROC = 190 ft / min**

b **Climb ETI = 5.37 min**