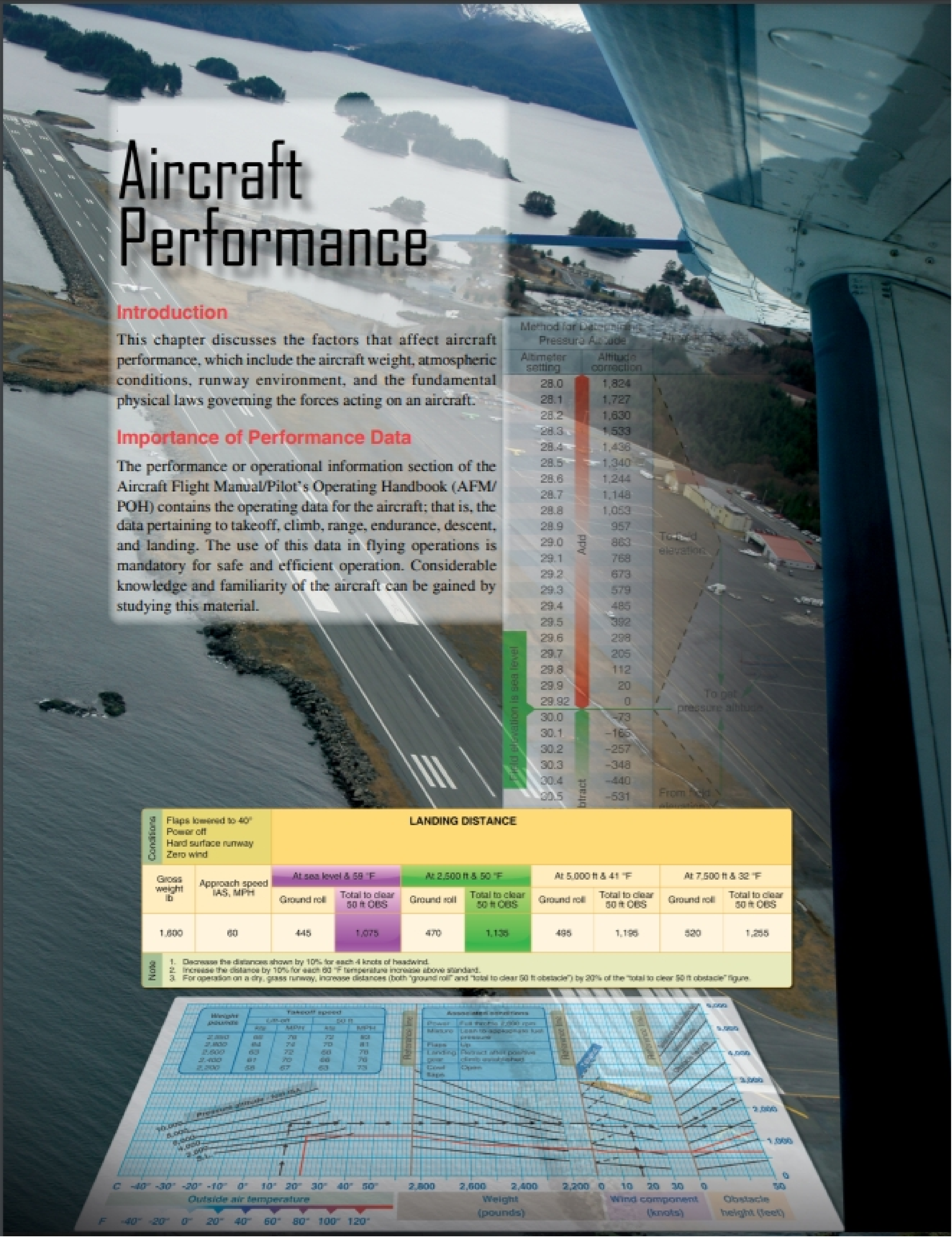

Aircraft Performance

Introduction

This chapter discusses the factors that affect aircraft performance, which include the aircraft weight, atmospheric conditions, runway environment, and the fundamental physical laws governing the forces acting on an aircraft.

Importance of Performance Data

The performance or operational information section of the Aircraft Flight Manual/Pilot's Operating Handbook (AFM/POH) contains the operating data for the aircraft; that is, the data pertaining to takeoff, climb, range, endurance, descent, and landing. The use of this data in flying operations is mandatory for safe and efficient operation. Considerable knowledge and familiarity of the aircraft can be gained by studying this material.

Method for Determining Pressure Altitude

Altimeter setting	Altitude correction
28.0	1,824
28.1	1,727
28.2	1,630
28.3	1,533
28.4	1,436
28.5	1,340
28.6	1,244
28.7	1,148
28.8	1,053
28.9	957
29.0	863
29.1	768
29.2	673
29.3	579
29.4	485
29.5	392
29.6	298
29.7	205
29.8	112
29.9	20
29.92	0
30.0	−73
30.1	−165
30.2	−257
30.3	−348
30.4	−440
30.5	−531

Conditions: Flaps lowered to 40°, Power off, Hard surface runway, Zero wind	LANDING DISTANCE								
Gross weight lb	Approach speed IAS, MPH	At sea level & 59 °F		At 2,500 ft & 50 °F		At 5,000 ft & 41 °F		At 7,500 ft & 32 °F	
		Ground roll	Total to clear 50 ft OBS	Ground roll	Total to clear 50 ft OBS	Ground roll	Total to clear 50 ft OBS	Ground roll	Total to clear 50 ft OBS
1,600	60	445	1,075	470	1,135	495	1,195	520	1,255

Note
1. Decrease the distances shown by 10% for each 4 knots of headwind.
2. Increase the distance by 10% for each 60 °F temperature increase above standard.
3. For operation on a dry, grass runway, increase distances (both "ground roll" and "total to clear 50 ft obstacle") by 20% of the "total to clear 50 ft obstacle" figure.

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Chapter 5

FLIGHT PERFORMANCE AND PLANNING

This is certainly one of the most important subjects in the syllabus. We do nothing without planning, even though we may not be aware of it at the time. Walking back to the dining room for lunch after the morning's lectures, we plan our route each time. Sometimes there is a need to go via the office, or even the toilet. Occasionally the weather forces us into breaking out of a set routine, and then we have no choice but to reconsider our options.

The same thing happens to us each and every time we fly. The same conditions are very seldom, if ever, encountered from one flight to another. Even on the same day conditions in the afternoon are never the same as they were in the morning. Temperature, pressure, wind and humidity are constantly changing, and each one affects the aircraft differently

Introduction

1. This chapter discusses the factors that affect aircraft performance, which include the aircraft weight, atmospheric conditions, runway environment, and the fundamental physical laws governing the forces acting on an aircraft.

2. The performance or operational information section of the Aircraft Flight Manual/Pilot's Operating Handbook (AFM/ POH) contains the operating data for the aircraft; that is, the data pertaining to takeoff, climb, range, endurance, descent, and landing. The use of this data in flying operations is mandatory for safe and efficient operation. Considerable knowledge and familiarity of the aircraft can be gained through study of this material.

3. It must be emphasized that the manufacturers' information and data furnished in the AFM/POH is not standardized. Some provide the data in tabular form, while others use graphs. In addition, the performance data may be presented on the basis of standard atmospheric conditions, pressure altitude, or density altitude. The performance information in the AFM/POH has little or no value unless the user recognizes those variations and makes the necessary adjustments.

4. To be able to make practical use of the aircraft's capabilities and limitations, it is essential to understand the significance of the operational data. The pilot must understand the basis of the performance data, as well as the meanings of the various terms used in expressing performance capabilities and limitations.

PERFORMANCE

Abbreviations, Terminology & Definitions Applicable to Performance

Airspeed terminology (refer to chapter 2 para 285)

ASI	Airspeed indicator.
IAS	Indicated airspeed.
CAS	Calibrated airspeed.
RAS	Rectified airspeed.
EAS	Equivalent airspeed.
TAS	True airspeed.
GS	Groundspeed.

Distance terminology (refer to chapter 3 para 55)

ANM	Air nautical miles.
SAD	Still air distance.
GNM	Ground nautical miles.

Performance terminology (refer to the chapter 5 para 54)

SR	Specific range.
SFC	Specific fuel consumption.

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Temperature terminology (refer to chapter 4 para 7)

IOAT
: Indicated Outside Air Temperature as read from the indicator (not corrected)

OAT
: Outside Air Temperature (corrected)

Temp Dev
: The difference between the actual OAT and the temperature of that level in the ISA atmosphere

General speed definitions

V_a Design Manoeuvring Speed. This is the maximum speed at which full aerodynamic control can be applied without overstressing the aircraft.

V_s Stall Speed. This is the minimum steady flight speed at which the aircraft is controllable.

V_{so} Stall Speed in the landing configuration.

V_{ne} Never Exceed Speed. This is the maximum speed of the aircraft, it must never be exceeded.

Take-off and climb speed definitions

V_r Rotation Speed. This is the speed at which the rotation of the aircraft is initiated. The speed cannot be less than V_1 or less than 1.05 times V_{mc}. With an engine failure, it must also allow for the acceleration to V_2 at the 35-foot height at the end of the runway.

V_{lof} Lift Off Speed. This is the speed at which the aircraft first becomes airborne, the wheels leave the ground.

V_2 Take-Off Safety Speed. This is essentially the best one-engine operative angle of climb speed for the aircraft and must be attained at the 35-foot height at the end of take-off distance required. It may not be less than 1.2 V_s with the critical engine inoperative.

V_x Best Angle of Climb Speed. This is when the greatest vertical distance is gained for the least horizontal distance travelled.

V_y Best Rate of Climb Speed. This is when the least time is taken for the greatest vertical distance gained.

Landing speed definitions

V_{fe} Maximum Flaps Extended Speed. This is the maximum speed of the aircraft with the flaps extended.

V_{fo} Maximum Flaps Operating Speed. This is the maximum speed of the aircraft with the flaps operating, extending or retracting.

V_{le} Maximum Landing Gear Extended Speed. This is the maximum speed of the aircraft with the landing gear extended.

V_{lo} Maximum Landing Gear Operating Speed. This is the maximum speed of the aircraft with the landing gear operating, extending or retracting.

V_{ref} Reference Speed. This is the reference speed of the aircraft in the landing configuration, it may not be less than 1.3 V_{so}. This is the required speed at the 50-foot height above the threshold of the runway.

Pressure and Temperature

5. Although the atmosphere was covered in Meteorology, it is necessary to review two dominant factors, pressure and temperature, because these two characteristics of the atmosphere have a major effect on performance.

6. Though there are various kinds of pressure, pilots are mainly concerned with atmospheric pressure. It is one of the basic factors in weather changes, helps to lift the aircraft, and actuates some of the most important flight instruments in the aircraft. These instruments often include the altimeter, the airspeed indicator (ASI), the vertical speed indicator, and the manifold pressure gauge. The density of air has significant effects on the aircraft's performance. As air becomes less dense, it reduces:

a. Power, because the engine takes in less air.

b. Thrust, because the propeller is less efficient in thin air.

c. Lift, because the thin air exerts less force on the aerofoils.

The pressure of the atmosphere varies with time and altitude.

7. Pressure altitude is the height above the theoretical level where the pressure of the atmosphere is 1013.2 hPa. As atmospheric pressure changes, this level may be below, at, or above sea level. Pressure altitude is important as a basis for determining aircraft performance, as well as for assigning flight levels.

8. Density altitude is pressure altitude corrected for nonstandard temperature. As the density of the air increases (lower density altitude), aircraft performance increases. Conversely, as air density decreases (higher density altitude), aircraft performance decreases. Density altitude is determined by first finding pressure altitude, and then correcting this altitude for nonstandard temperature variations. The density of the air, of course, has a pronounced effect on aircraft and engine performance. Regardless of the actual altitude at which the aircraft is operating, it will perform as though it were operating at an altitude equal to the existing density altitude.

Example:

The higher the density altitude, the lower the air density and performance of the aircraft's engines. Runway length requirements increase with a potential corresponding reduction in the take-off weight.

9. Most performance graphs contain positioning for pressure altitude and temperature; a calculation to determine density altitude is not required.

Solution:

To calculate density altitude, convert airfield elevation to pressure altitude, then compute using a van. computer.

Airfield Elevation	3275 ft	QNH 1025 hPa
	-360 ft	30 ft x 12 hPa
Pressure Altitude	2 915 ft	QNE 1013 hPa

OAT +32°C DA 5489 feet.

Pressure Datum's

10. The sub-scale of an altimeter is normally set to one of three datum's:

QFE

The barometric altimeter setting which will cause the altimeter to read zero, measured above a fixed point from the earth's surface, usually observed from an airfield datum point.

QNH

The barometric altimeter setting which will cause the altimeter to read airfield elevation when on the airfield. The QFE is reduced to mean sea level (MSL) pressure using the standard atmosphere temperature lapse rate. The pressure altimeter is calibrated to the standard atmosphere, and so when QNH is set on the altimeter sub-scale the instrument indicates the airfield elevation.

QNE

W hen flying above the transition altitude the barometric altimeter is set to1013 hPa to maintain a specific flight level. A Flight Level is a standard nominal altitude of an aircraft, in hundreds of feet, measured from the ISA pressure datum of 1013.25 hPa.

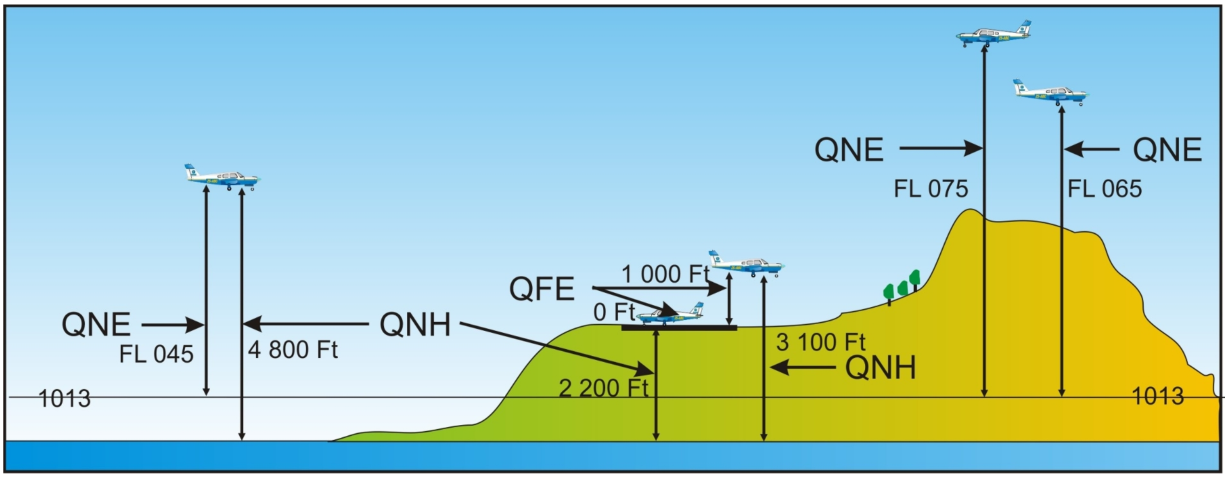

Fig 5.1. Pressure Datum's

ISA Deviation

11. ISA Deviation is the difference between the ambient & ISA temperatures. The ISA temperature at sea level is +15ºC, this is the starting point of calculating the ISA deviation. If the ambient temperature at sea level is +20 ºC, then it will be ISA +5, because it is 5ºC warmer than the ISA temperature. If it is ISA +5 conditions, the temperature at FL210 will be -22 ºC.

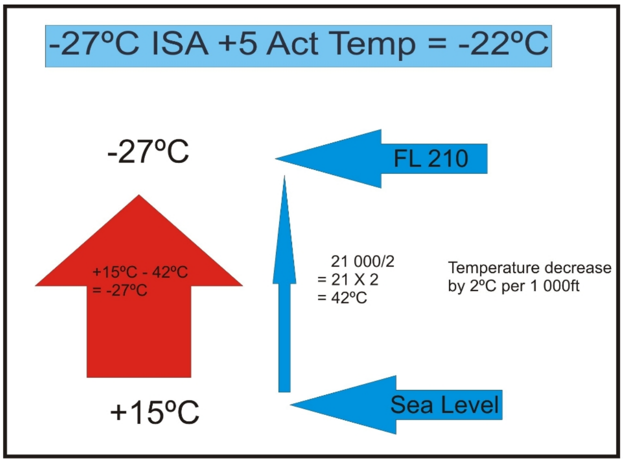

Fig 5.2. ISA Deviation

AIRCRAFT PERFORMANCE

12. Performance is a term used to describe the ability of an aircraft to accomplish certain things that make it useful for certain purposes. For example, the ability of an aircraft to land and take off in a very short distance is an important factor to the pilot who operates in and out of short, unimproved airfields. The ability to carry heavy loads, fly at high altitudes at fast speeds, or travel long distances is essential performance for operators of airline and executive type aircraft. The primary factors most affected by performance are the takeoff and landing distance, rate of climb, ceiling, payload, range, speed, manoeuvrability, stability, and fuel economy. Some of these factors are often directly opposed: for example, high speed versus short landing distance, long range versus great payload, and high rate of climb versus fuel economy. It is the pre-eminence of one or more of these factors that dictates differences between aircraft and explains the high degree of specialization found in modern aircraft. The various items of aircraft performance result from the combination of aircraft and power plant characteristics. The aerodynamic characteristics of the aircraft generally define the power and thrust requirements at various conditions of flight, while power plant characteristics generally define the power and thrust available at various conditions of flight. The matching of the aerodynamic configuration with the power plant is accomplished by the manufacturer to provide maximum performance at the specific design condition (eg, range, endurance, and climb).

13. The majority of pilot-caused aircraft accidents occur during the takeoff and landing phase of flight. Because of this fact, the pilot must be familiar with all the variables that influence the takeoff and landing performance of an aircraft and must strive for exacting, professional procedures of operation during these phases of flight. Takeoff and landing performance is a condition of accelerated and decelerated motion. For instance, during takeoff, an aircraft starts at zero speed and accelerates to the

takeoff speed to become airborne. During landing, the aircraft touches down at the landing speed and decelerates to zero speed. Takeoff or landing performance will depend on a number of factors. These factors include:

Weight

Any extra weight will require extra lift to overcome it. Speed and lift are directly related, and the Aircraft will only generate enough lift once it is flying fast enough. The heavier your aircraft, the longer it will take to get to take-off speed, and therefore, the more runway length it will require to do so. This increase in take-off distance required is about 20% for an increase in weight of 10%.

Airfield Elevation

The greater the elevation, the thinner the air. The engine needs as much as it can get, and if the airfield elevation is increased by 1000 feet, the take-off distance will increase by about 10%.

Temperature

Any increase in temperature will cause an increase in Density Altitude. This means that although an airfield is at sea level, an outside air temperature of 35 ° C will mean a density altitude of 2 275 feet. That will be the effective height at which the aircraft is actually working. This is due to the fact that 35° C at sea level is 20 ° C hotter than the Standard Atmosphere. An increase of 10 ° C will require a take-off distance increase of 10%. In the case mentioned above, the take-off distance would have been 20% more (This is also borne out by the fact that the "elevation" is effectively more than 2000 feet higher, which also mean a 20% would increase).

Runway Surface

All performance graphs are calculated for a "Paved, Level, Dry" runway surface. Change any of the three factors, and the take-off distance will change. If the runway is grass, then the take-off distance will increase. The increase will also depend on the length of the grass. Short grass (# 8 inches) will mean a 20% increase in the take-off distance. Longer grass ($ 8 inches) will increase the take-off distance by 30%.

Wet Runway

This is not much of a problem on a paved runway unless there is standing water. Most tarred runways are designed in such a way that surface water runs off. But on grass runways it is a different story. In the case of wet, short grass, the take-off distance will increase by 25%, and with wet, long grass, 30%.

Runway Slope

Very few runways are level. An uphill slope of 2% (2 ft for every 100 ft of length) will increase take-off distance by 10%.

Wind

A take-off is usually done into wind, but there are runways that may require you to take-off with a tailwind component. If the tailwind component is 10% of the lift off speed, then take-off distance will increase by 20%. An example of this: if take-off speed is 60 knots, a tail wing component of 6 knots will increase the take-off distance by 20%.

14. The performance graphs and graphs of most aircraft have one or more of the parameters mentioned above already factored in. If you have calculated a take-off distance using the Aircraft graphs, and some of the above mentioned parameters have not been factored in, those that have not been included have to be included in the calculation. If you are confronted by more than one of the above un-factored parameters, they are accumulative. If °T increases by 10°C (factor 1.1), and the weight increases by 10% (factor 1.2), the basic value must be multiplied by 1.1 and then the answer by 1.2.

Example:

You have calculated that the take-off distance on a paved, level, dry runway is 2 000 feet. But there is a 2% uphill slope, the runway is short grass, and it has been raining. The factors are 10% for the slope (increase by 1.1), 20% for grass (x 1.2), and 25% for the fact that the grass is wet (x 1,25). Take-off distance 2 000ft X 1.1 = 2 200ft X1.2 = 2 640ft X 1.25 = 3 300ft is th runway length required.

Take-off and Landing Distance Factors

VARIATION	INCREASE IN DISTANCE	FACTOR
10% increase in weight	20%	1.2
Increase of 1 000' of Rwy alt	10%	1.1
Increase in ET of 10 EC	10%	1.1
Dry grass $ 8"	20%	1.2
Dry grass # 8"	30%	1.3
W et grass $ 8"	25%	1.25
W et grass # 8"	30%	1.3
2% uphill slope	10%	1.1
Soft ground or snow	25%	1.25
TW C 10% of landing speed	20%	1.2

Performance Terminology

15. W hen we determine the performance of our aircraft, we have to establish what distances are available for take-off and landing from the airfield parameters and then we have to determine what are the distances required from the graphs from of the Flight Manual. Before we discuss distances, let’s look at definitions and terminology that’s used for take-off and landing performance.

Clearway

An area beyond the take-off runway over which an aircraft may accelerate after take-off. It must be at least 300ft either side of the centre line of the runway and must have an elevation equal or less than the elevation of the runway threshold. It may not be longer than 1.5 X that of the runway length or the restriction as per Flight Manual. It must be free of obstacles, promulgated and under control of the airport authorities.

Stopway

An area beyond the take-off runway that can be used by an aircraft to stop during an emergency. It must be able to support the aircraft weight, have a coefficient equal or greater than the runway and be free of obstacles. It must be promulgated for use in decelerating an aircraft during an emergency and it must be under the control of the airport authorities. You can only use the stopway during emergency planning, not for planning normal flying.

Displaced Threshold

A threshold located at a point on the runway other than the designated beginning of the runway, marked with arrows painted on the runway prior to the displaced threshold bar.

Climb Gradient

The ratio of change in height proportional to horizontal distance travelled in the same time.

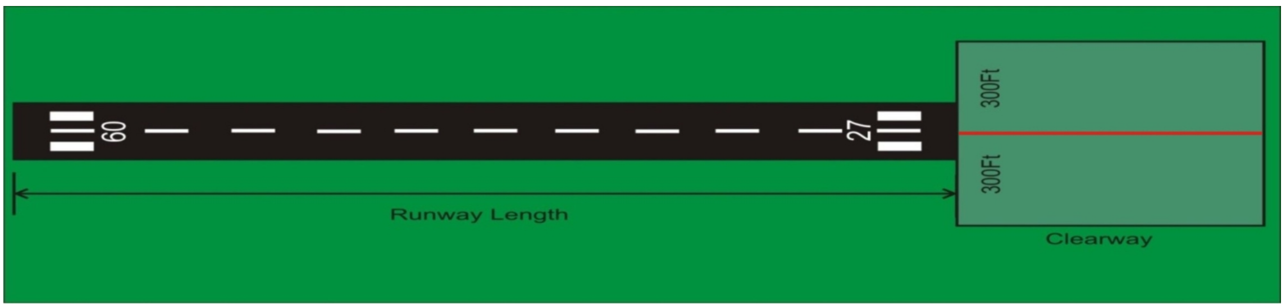

Fig 5.3. Clearway

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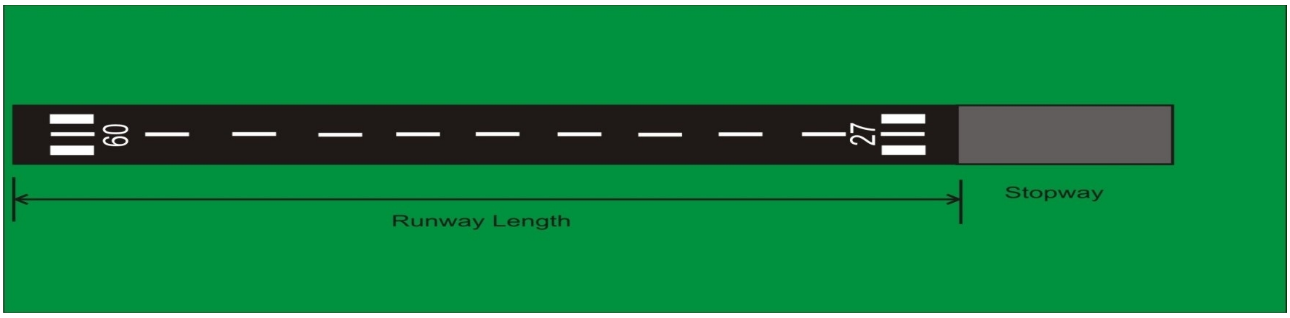


Fig 5.4. Stopway

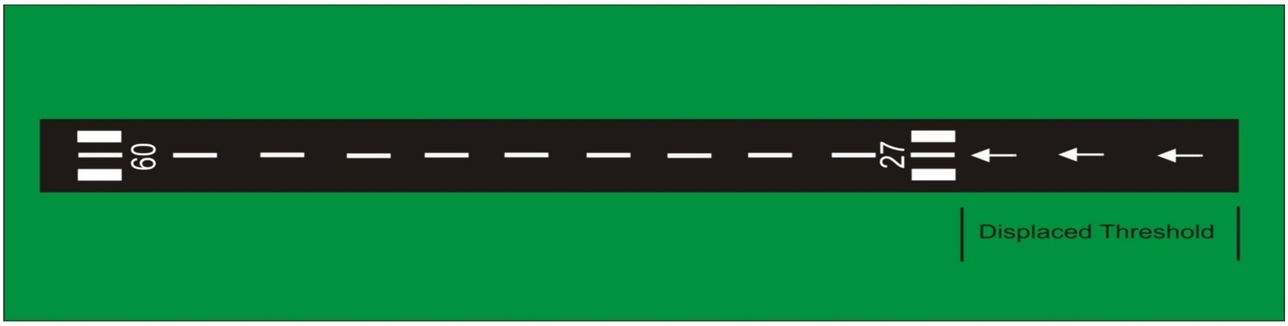


Fig 5.5. Displaced Threshold

Take-off Run

The distance required to accelerate an aircraft from brake release rotating at V_r and lift off at V_{lof}, when the wheels leave the ground.

Take-off Distance

The distance required to accelerate an aircraft from brake release rotating at V_r and reaching V_2 at 35ft AGL.

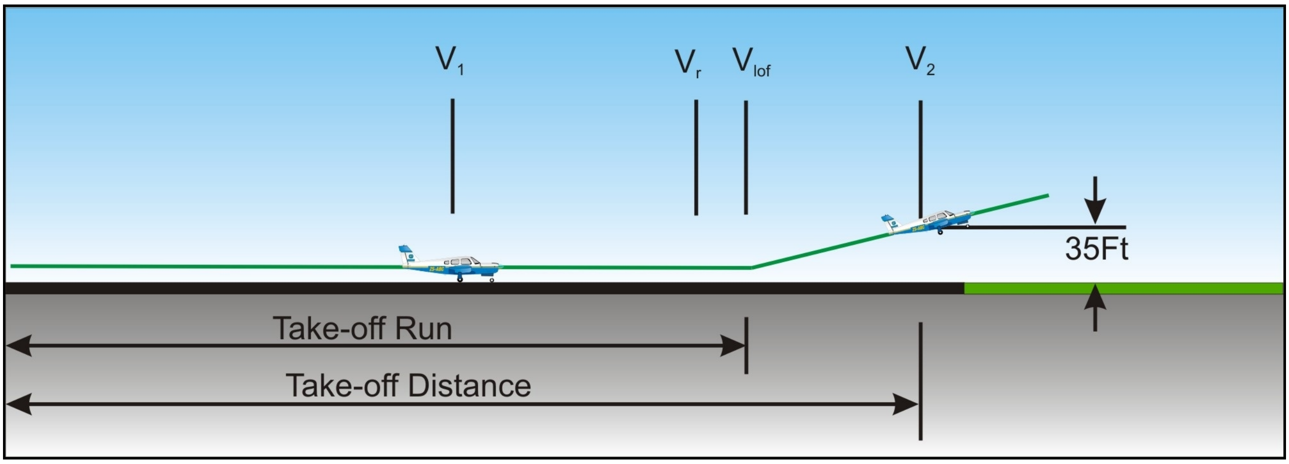


Fig 5.6. Take-off Run and Take-off Distance

Landing Distance

The distance required from 50ft above the threshold, at V_{ref}, to land and decelerate an aircraft to a full stop.

Ground Roll

The distance required from touch down and decelerate an aircraft to a full stop.

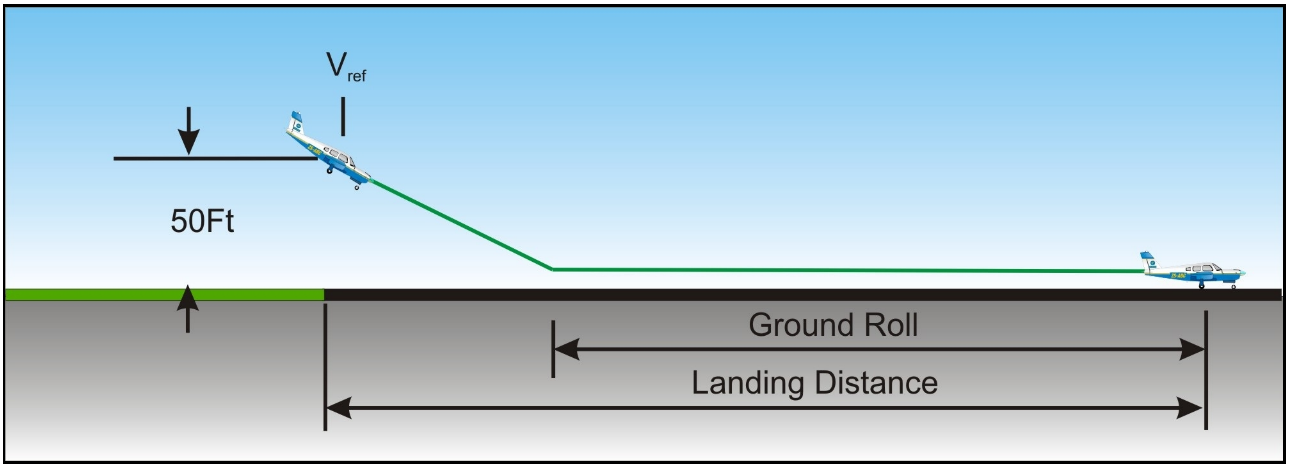


Fig 5.7. Landing Distance

Flight Profile

16. W hen planning a flight it can be broken down into phases:

- Take-off
- Climb
- Cruise
- Descent
- Landing
- General

17. Suitable graphs may be used to solve all the phases of flight.

Take-Off Performance

18. For any particular take-off you must ensure that the distances required for take-off, in the prevailing conditions, do not exceed the distances available at the take-off airfield.

19. First you must calculate available distances according to the take-off airfields parameters:

Take-Off Run Available (TORA)

20. The length of the runway suitable for normal operations, just the runway length.

Take-Off Distance Available (TODA)

The length of the runway plus any clearway promulgated for that runway, the stopway can be taken as clearway for TODA.

Accelerate Stop Distance Available (ASDA)

The length of the runway plus stopway promulgated for that runway, if available.

21. Takeoff graphs are typically provided in several forms and allow a pilot to determine the Take-Off Run Required (TORR) and Take-Off Distance Required (TODR) of the aircraft with no flaps or with a specific flap configuration. The takeoff run and take-off distance graphs provides for various aircraft weights, altitudes, temperatures, winds, and obstacle heights.

Example:

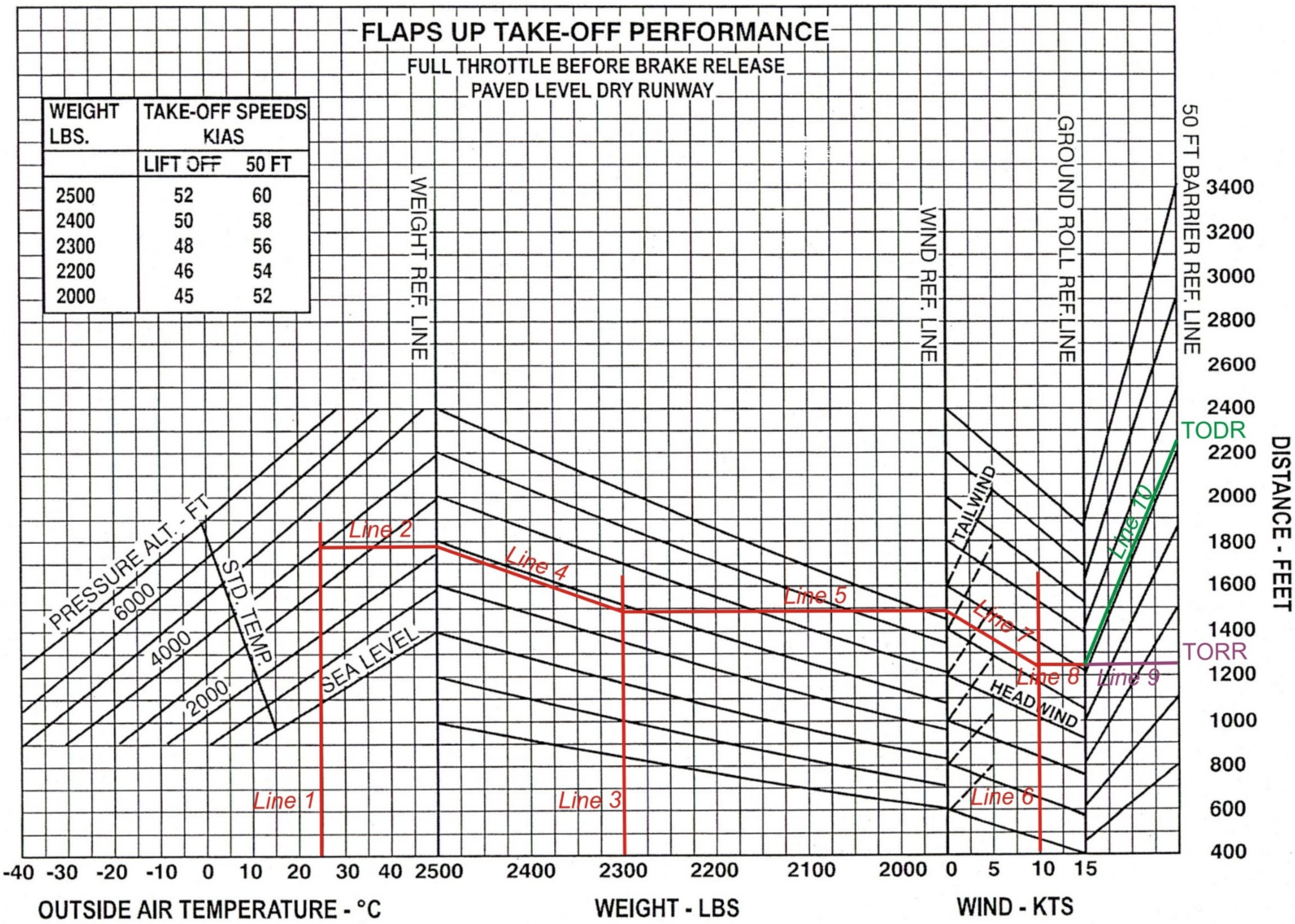
W hat is the TORR and TODR for the following conditions?
Airfield PA is 4 000ft
OAT is 25ºC
TOW is 2 300lbs
HW C is 10kts
Flaps up

22. Ensure that you are using the correct graph,

check and recheck the heading of the graph with parameters given. The example graphs from CAA compensate for density, weight and wind, it does not compensate for runway surface and runway slope. If necessary you must compensate for surface and slope by applying the correct distant factors. On the example graphs from CAA you determine the TORR and TODR on one graph, it is possible that it could be separate graphs.

23. Draw a line vertical line on the 25ºC line until it crosses the 4 000ft PA line (Line 1). W here the two cross, draw a horizontal line until it crosses the weight reference line (Line 2). Draw a vertical line on 2 300lbs weight line (Line 3). Follow the guideline from where Line 2 crosses the weight reference line until it crosses Line 3, the 2 300lbs weight line (Line 4).

24. W here Line 3 & 4 cross, draw a horizontal line to the wind reference line (Line 5). Draw a vertical line on the 10kts wind line (Line 6). Follow the guideline from where Line 5 crosses the wind reference line until it crosses Line 6, the 10kts wind line (Line 7). Daw a horizontal line until it crosses the Ground roll reference line (Line 8). Extend the horizontal line to the right, this is the TORR which is 1 250ft (Line 9). Follow the guideline from where Line 8 crosses the Ground roll reference line until it crosses the 50ft barrier line (Line 10). This is the TODR which is 2 250ft.



Graph 5.1. Take-off Performance

25. If you have calculated the TORA or TODA, you can determine your MTOW by reversing the process.

Example:

W hat is the MTOW for the following conditions?

Airfield PA is 4 000ft
OAT is 25ºC
HW C is 10kts
Flaps up
TORA is 1 250ft
TODA is 2 450ft

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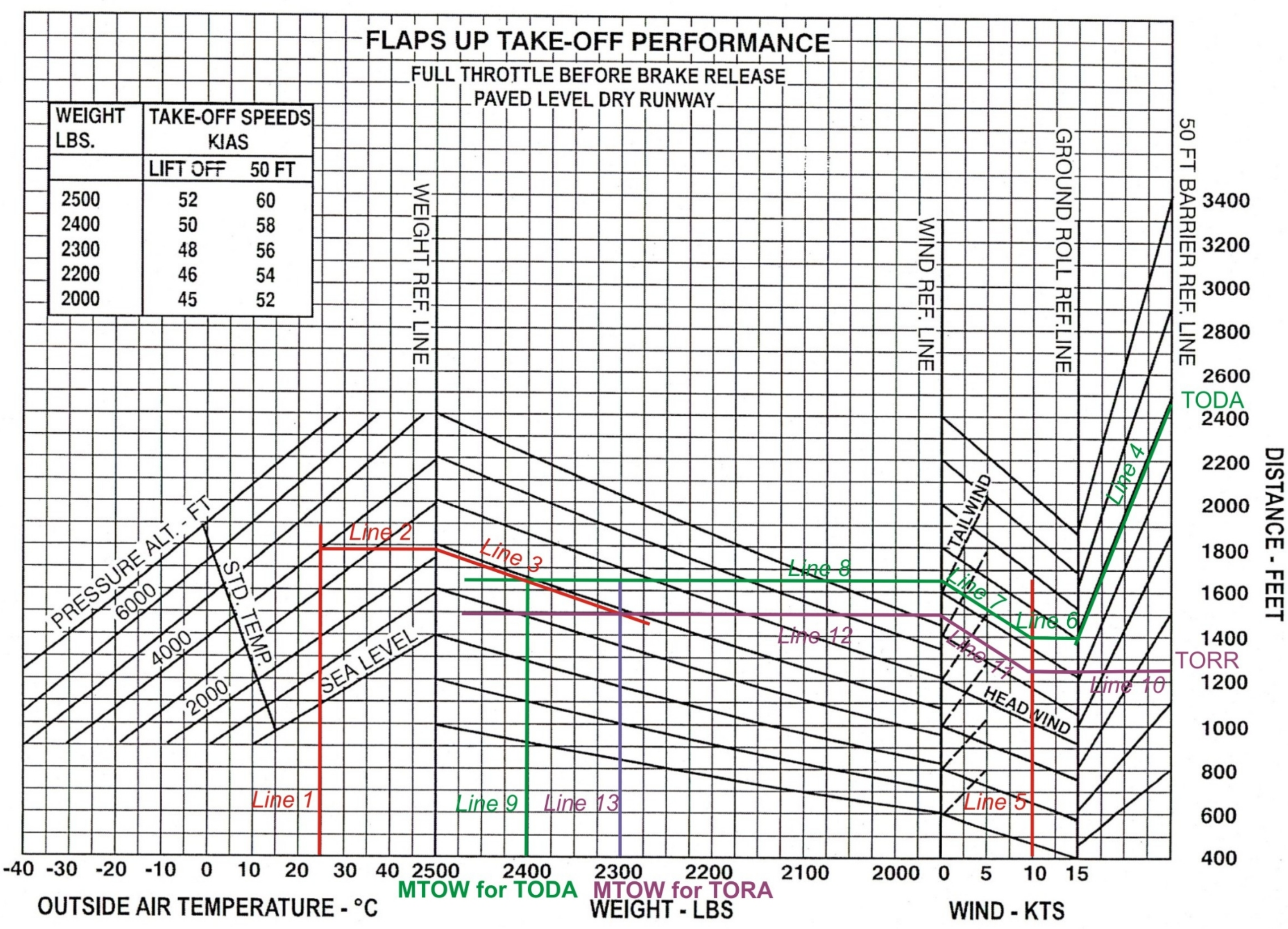
26. Again, ensure that you are using the correct graph, check and recheck the heading of the graph with parameters given.

27. Draw a vertical line on the 25ºC line until it crosses the 4 000ft PA line (Line 1). W here the two cross, draw a horizontal line until it crosses the weight reference line (Line 2). Following the guide lines, draw a line to the right (Line 3). Now we start from the other end of the graph. Let's do TODA first. From the 2 450ft mark at the end of the graph, follow the guideline to the ground roll reference line (Line 4). Draw a vertical line on the 10kts wind line (Line 5). Draw a horizontal line from where Line 4 crosses the ground roll reference line until it cross the 10kts wind line (Line 6). Follow the guideline until it crosses the wind reference line (Line 7). Draw a horizontal line from where Line 7 crosses the wind reference line to the left (Line 8). W here Line 8 and 3 crosses, draw a line vertically down, read off the MTOW for these parameters (Line 9). The MTOW for TODA is 2 400lbs.

28. You must determine the MTOW for TORA. Again we start from the other end of the graph. Most of the lines are already drawn on the graph. From the 1 250ft mark at the end of the graph draw a horizontal line until it cross the 10kts wind line, Line 5 (Line 10). Follow the guideline until it crosses the wind reference line (Line 11). Draw a horizontal line from where Line 11 crosses the wind reference line until it crosses Line 3 (Line 12). W here Line 12 and 3 cross, draw a line vertically down, read off the MTOW for these parameters (Line 13). The MTOW for TORA is 2 300lbs.



Graph 5.2. Take-off Performance

The lesser weight is the limiting weight. The MTOW for these parameters will be 2 300lbs.

Climb Performance

29. Climb performance is a result of using the aircraft's potential energy. The maximum angle of climb would occur at greatest difference between thrust available and thrust required; i.e., for the propeller-powered aircraft, the maximum excess thrust and angle of climb will occur at some speed just above the stall speed. Thus, if it is necessary to clear an obstacle after takeoff, the propeller-powered aircraft will attain maximum angle of climb at airspeed close to—if not at—the takeoff speed. Of greater interest in climb performance are the factors that affect the rate of climb. The vertical velocity of an aircraft depends on the flight speed and the inclination of the flightpath. In fact, the rate of climb is the vertical component of the flightpath velocity. The climb performance of an aircraft is affected by certain variables. A change in an aircraft's weight produces a twofold effect on climb performance. First, a change in weight will change the drag and the power required. This alters the reserve power available, which in turn, affects both the climb angle and the climb rate. Secondly, an increase in weight will reduce the maximum rate of climb, but the aircraft must be operated at a higher climb speed to achieve the smaller peak climb rate.

30. An increase in altitude also will increase the power required and decrease the power available. Therefore, the climb performance of an aircraft diminishes with altitude. The speeds for maximum rate of climb, maximum angle of climb, and maximum and minimum level fight airspeeds vary with altitude. As altitude is increased, these various speeds fin ally converge at the absolute ceiling of the aircraft. At the absolute ceiling, there is no excess of power and only one speed will allow steady, level flight. Consequently, the absolute ceiling of an aircraft produces zero rate of climb. The service ceiling is the altitude, at which the aircraft is unable to climb at a rate greater than 100 feet per minute (fpm),

31. To determine climb performance we will use the sample graph as supplied by CAA.

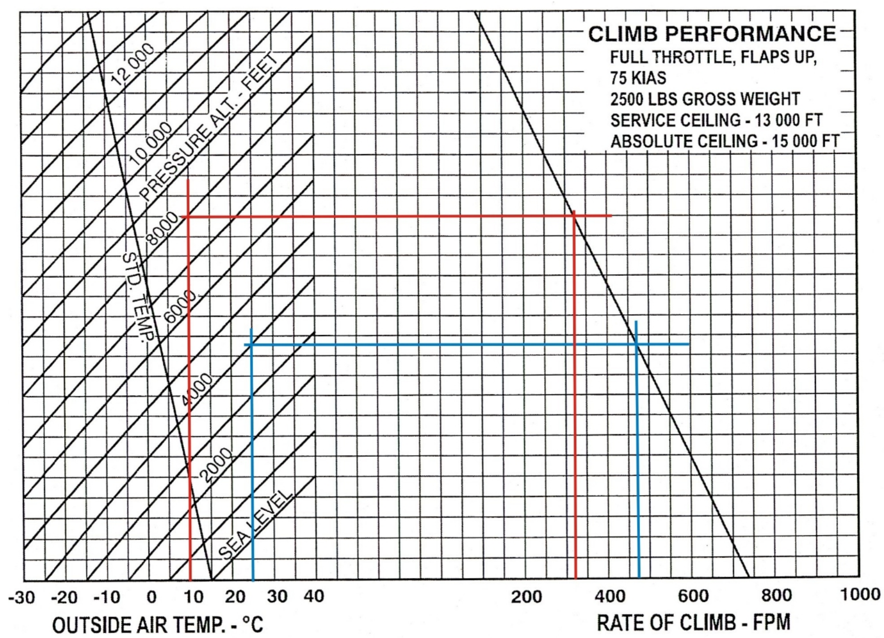
Example:

W hat is the Rate of Climb (ROC) for the following conditions?

a. PA is 4 000ft
OAT is 25ºC

b. PA is 8 000ft
OAT is 10ºC

32. Draw vertical lines from the given temperatures until they cross the given PA's. From where they cross draw horizontal lines to cross the reference line. From these crossings, draw vertical lines down and read off the rate of climb.



Graph 5.3. Climb Performance

The ROC for "a" would be 470fpm and "b: would be 320fpm.

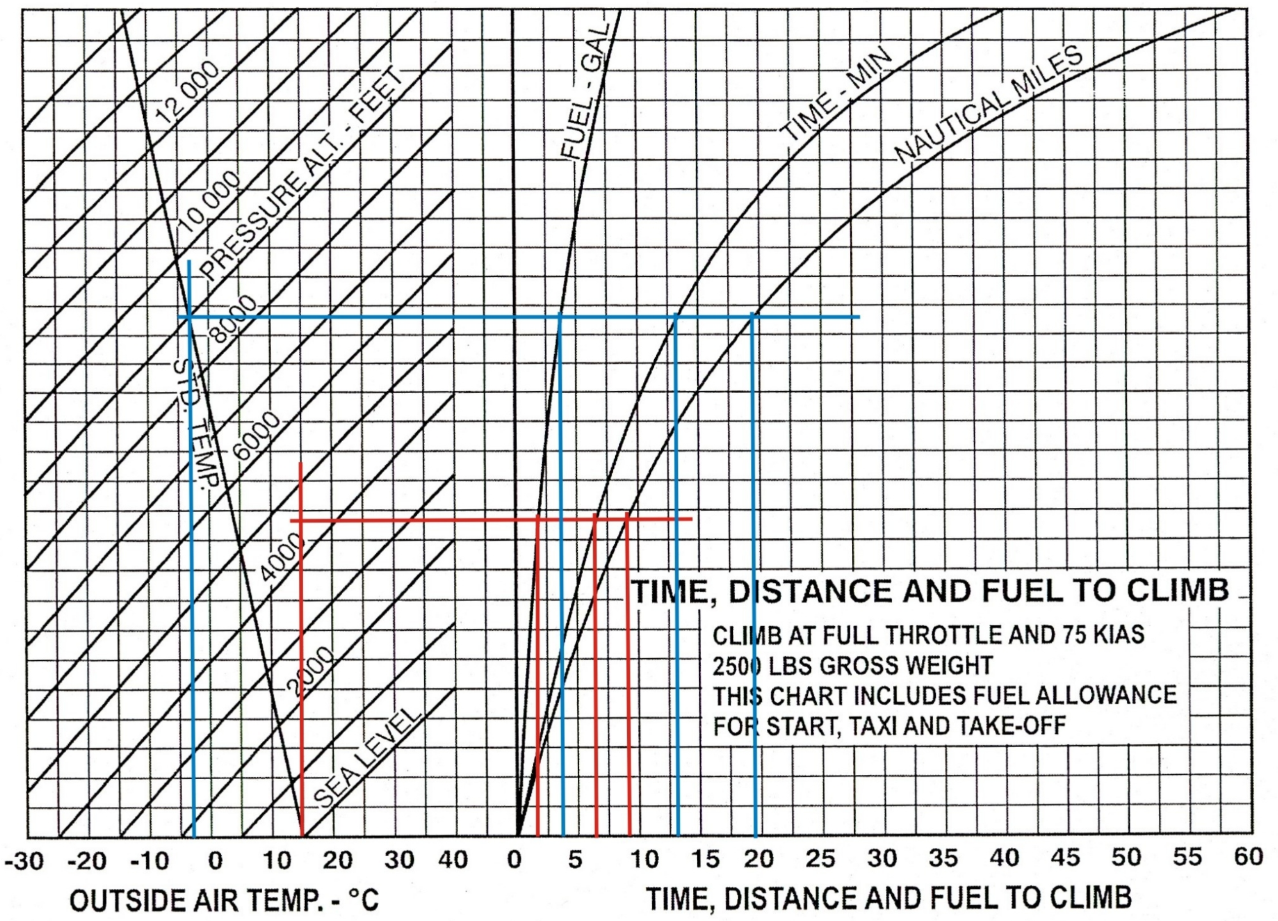
33. To determine time, distance and fuel to climb we will use the sample graph as supplied by CAA. If you are departing from an inland airfield (ie not at sea level) then you need to calculate the climb in 3 steps:

1. From sea level to cruise level
- 2. From sea level to airfield elevation
= 3. From airfield elevation to cruise level

Example:

Determine the time, distance and fuel to climb from an airfield 4500ft amsl to F090 under ISA conditions, aircraft weight 2500 lbs. (Temp at 4500' will be +15°C, and at F090 will be -3°C).

34. Follow the same procedures as the previous graphs. Start with temperature, to the pressure altitude, then to the fuel, time and distance lines and then to the bottom again to determine your fuel, time and distance to climb.



Graph 5.4. Time, Distance and Fuel to Climb

	Fuel	Tim e	Distance
SL to FL 090	4.0gal	0:13	19nm
SL to 4 500 ft	2.0gal	0:07	9nm
	2.0gal	0:06	10nm

It will take you 0:06 minutes, you will travel 10nm (remember this is still air distance) and will use 2 gallons of fuel to climb from 4 500ft to FL 090.

35. The procedure is the same for both climb and descent. Determine the Time, Fuel and Distance from the respective graphs. Use the Time and Distance to calculate TAS, because the distance from the graph is still air distance, and then apply wind to your track to get heading & groundspeed. With the calculated groundspeed you can now calculate distance flown as leg time is unaffected by wind.

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Cruise Performance

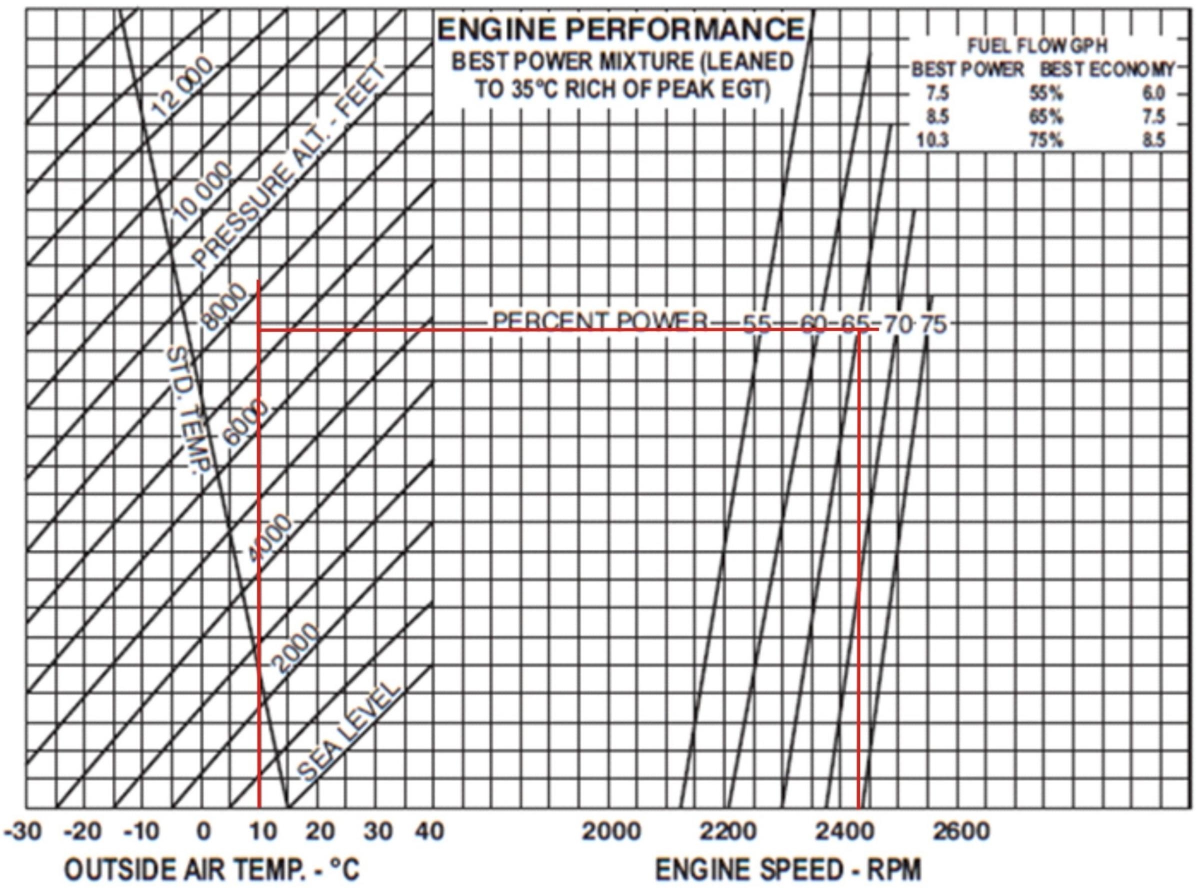
36. All of the principal components of flight performance involve steady-state flight conditions and equilibrium of the aircraft. For the aircraft to remain in steady level flight, equilibrium must be obtained by a lift equal to the aircraft weight and a power plant thrust equal to the aircraft drag. Thus, the aircraft drag defines the thrust required to maintain steady, level flight.

37. Cruise graph and table information is based on actual flight tests conducted in an aircraft of the same type. This information is extremely useful when planning a cross country flight to predict the performance and fuel consumption of the aircraft. Manufacturers produce several different graphs and tables for cruise performance. These graphs and tables include everything from fuel, time, to the best power setting during cruise, to cruise range performance.

38. The first graph to check for cruise performance is engine performance, to calculate your engine speed for different power settings. Then we can determine our speed and range for either performance or economy cruise and our endurance for a specific flight.

Example:

Determine the engine speed for a flight at 7 500ft, temperature 10ºC at 65% power? Use the same graph techniques as for the previous graphs.



Graph 5.5. Engine Performance

You have to set 2 430RPM to maintain a 65% power cruise for these conditions.

39. W e have determined our power setting for these conditions. Now we have to determine our speed and range for either power performance or economy cruise.

Example:

Determine the TAS and Range for a flight at 7 500ft, temperature 10ºC at 65% power? Use the same graph techniques as for the previous graphs.

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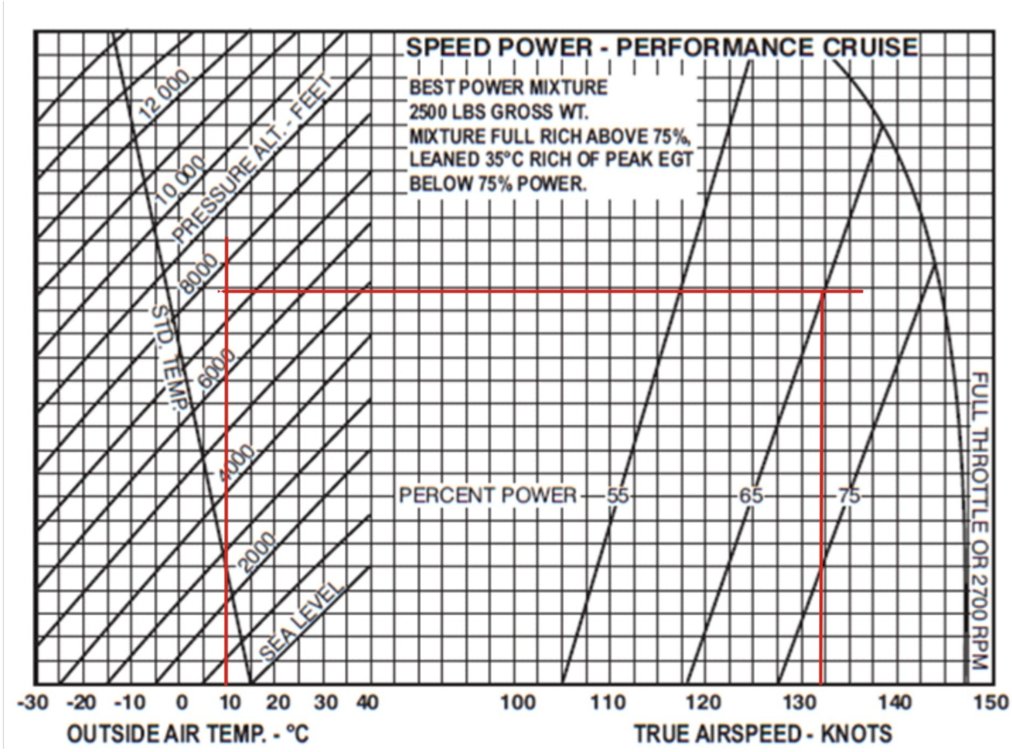
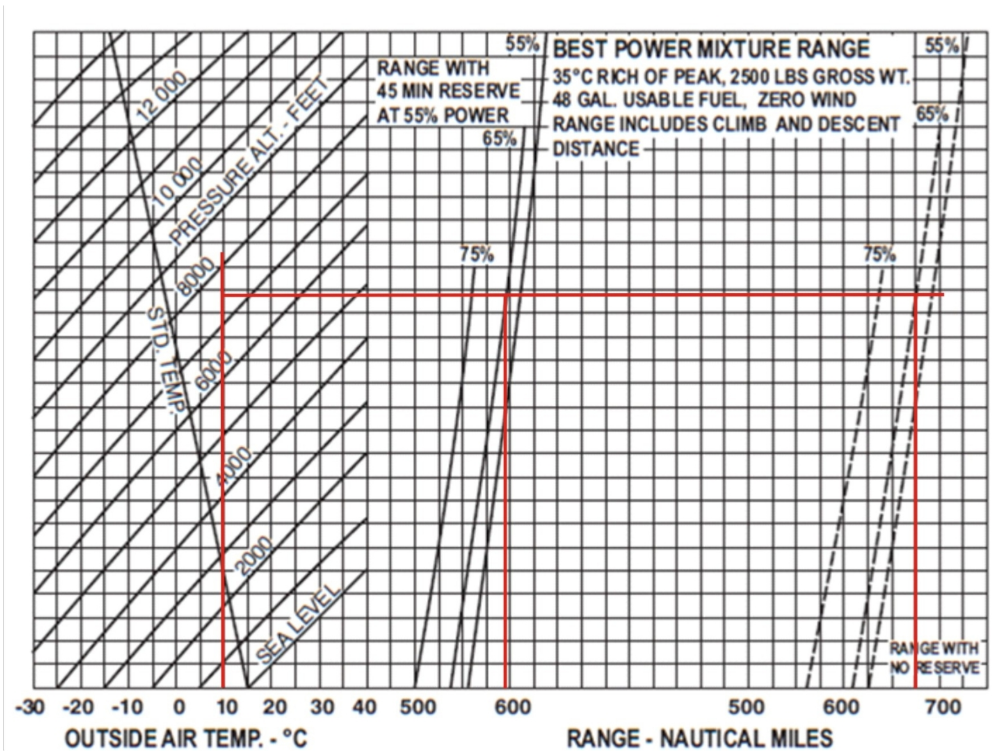


Graph 5.6. Speed Power Performance Cruise

Your TAS will be 132kts.



Graph 5.7. Best Power Mixture Range

Your range with reserves will be 590nm. and without reserves will be 675nm.

40. We now have to determine our endurance. mixture.
Endurance is always done at the best economy

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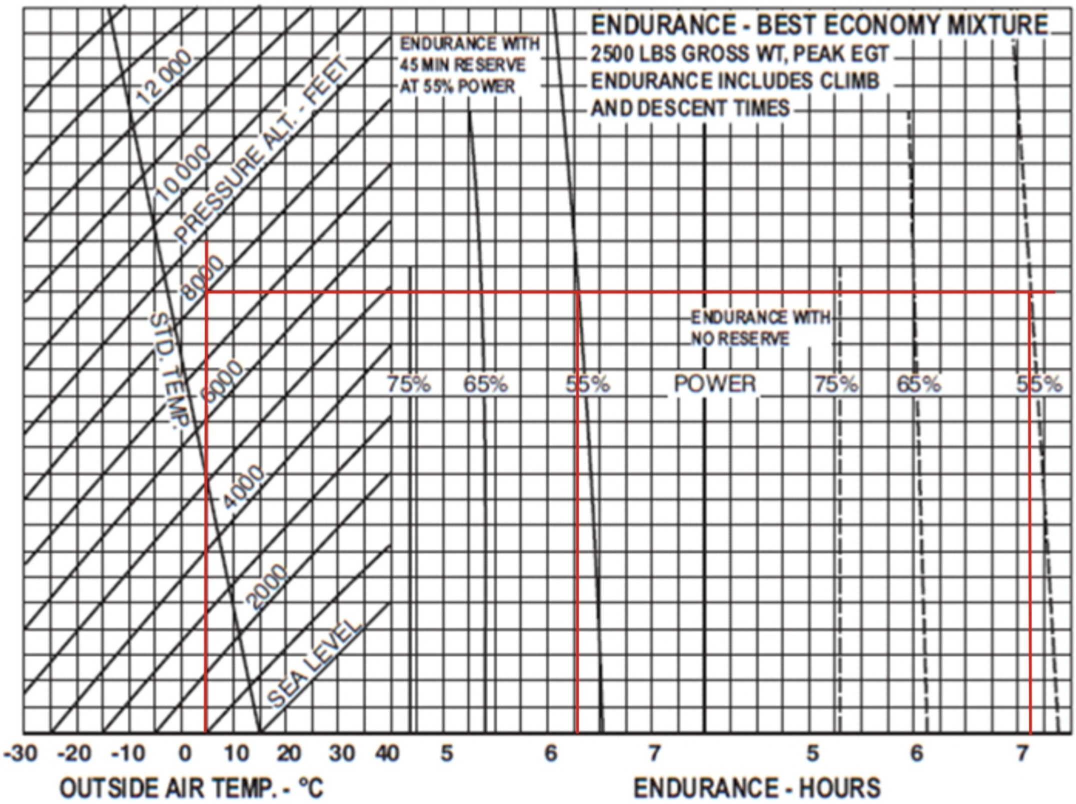
Example:

Determine the endurance at 8 000ft, temperature 5ºC at 55% power?

41. Use the same graph techniques as for the previous graphs.



Graph 5.8. Endurance - Best Economy Mixture

The endurance with reserves will be 06:16 and without reserves will be 07:07.

Descent

42. The same technique as we have used for the climb, is used to determine time, distance and fuel to descent. W e will use the sample graph as supplied by CAA. If you are descending to an inland airfield (ie not at sea level) then you need to calculate the descend in 3 steps:

1. From cruise level
- 2. From airfield elevation to sea level
= 3. From cruise level to airfield elevation

43. Follow the same procedures as the previous graphs. Start with temperature, to the pressure altitude, then to the fuel, time and distance lines and then to the bottom again to determine your fuel, time and distance to descend. Remember you are descending to 4 500ft.

44. The procedure is the same for both climb and descent. Determine the Time, Fuel and Distance from the respective graphs. Use the Time and Distance to calculate TAS, because the distance from the graph is still air distance, and then apply wind to your track to get heading & groundspeed. With the calculated groundspeed you can now calculate distance flown as leg time is unaffected by wind.

Example:

Determine the time, distance and fuel to descend from FL 090 to 4500ft amsl under ISA conditions, aircraft weigh 2500 lbs. (Temp at 4500' will be +6°C, and at F090 will be -3°C).

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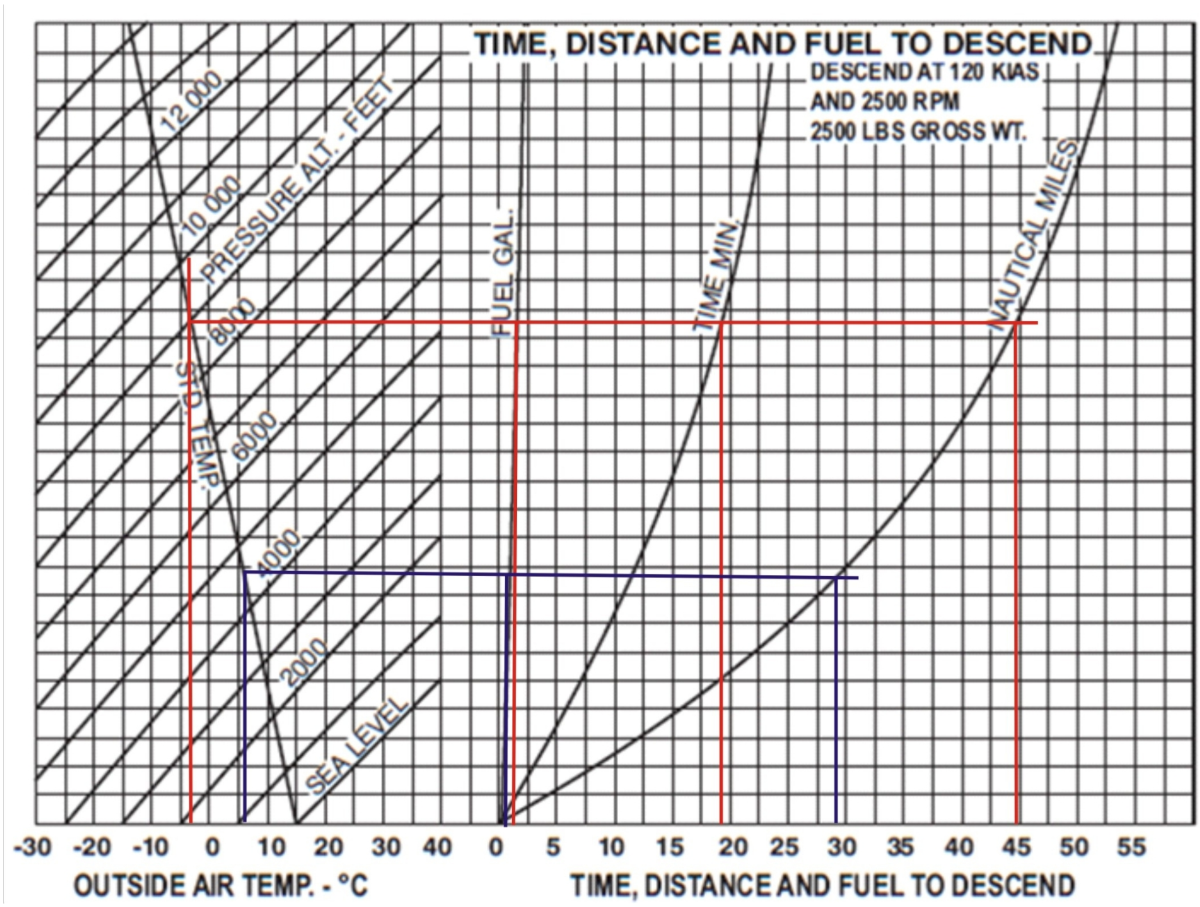


Graph 5.9. Time, Distance and Fuel to Descent

	Fuel	Tim e	Distance
FL 090 to SL	2.0gal	0:19	45nm
4 500 ft to SL	1.0gal	0:11	29nm
	1.0gal	0:08	16nm

It will take you 0:08 minutes, you will travel 16nm (remember this is still air distance) and will use 1.0 gallons of fuel to descend from FL 090 to 4 500ft.

Landing Performance

45. Landing performance is affected by variables similar to that affecting take-off performance. It is necessary to compensate for differences in density altitude, weight of the aircraft and wind. Like take-off performance graphs, landing distance information is available as landing ground roll and landing distance. As usual, read the associated conditions and notes in order to ascertain the basis of the graph information. Remember, when calculating landing distance that the landing weight will not be the same as the takeoff weight. The weight must be recalculated to compensate for the fuel that was used during the flight.

46. For any particular landing you must ensure that the distance required for landing, in the prevailing conditions, does not exceed the distance available at the landing airfield.

47. Landing Distance Available (LDA). Only the length of the runway can be used. If there is a displaced threshold in the landing direction, only the length from the displaced threshold to the end of the runway may be used. If the displaced threshold is on the opposite side of the landing direction, then the length from the displaced threshold to the end of the runway may be used as it is part of the ground roll.

48. Landing graphs are typically provided in several forms and allow a pilot to determine the

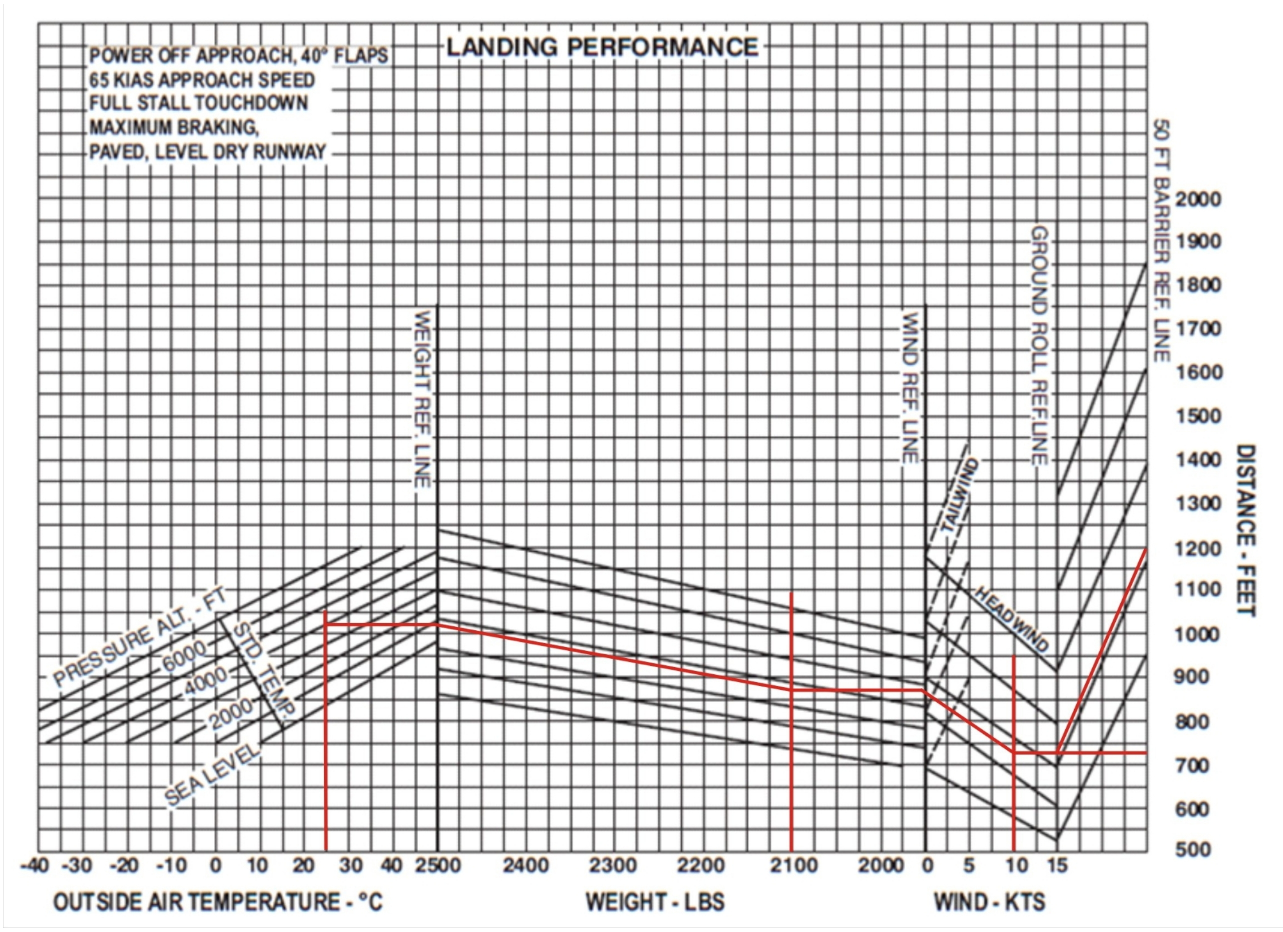
Landing Ground Roll and Landing Distance Required (LDR) of the aircraft with no flaps or with a specific flap configuration. The landing graphs provide for various aircraft weights, altitudes, temperatures, winds, and obstacle heights.

49. Ensure that you are using the correct graph, check and recheck the heading of the graph with parameters given. The example graphs from CAA compensate for density, weight and wind, they does not compensate for runway surface and runway slope. If necessary you must compensate for surface and slope by applying the correct distant factors. On the example graphs from CAA you determine the Landing Ground Roll and LDR on one graph; it is possible that it could be separate graphs.

Example:

W hat are the Landing Ground Roll and LDR for the following conditions?

Airfield PA is 4 000ft
OAT is 25ºC
LW is 2 100lbs
HW C is 10kts
40º Flaps



Graph 5.10. Landing Performance

In these conditions the Landing Ground Roll required will be 750ft and the LDR will be 1200ft.

50. If you have calculated the LDA, you can determine your MLW by reversing the process.

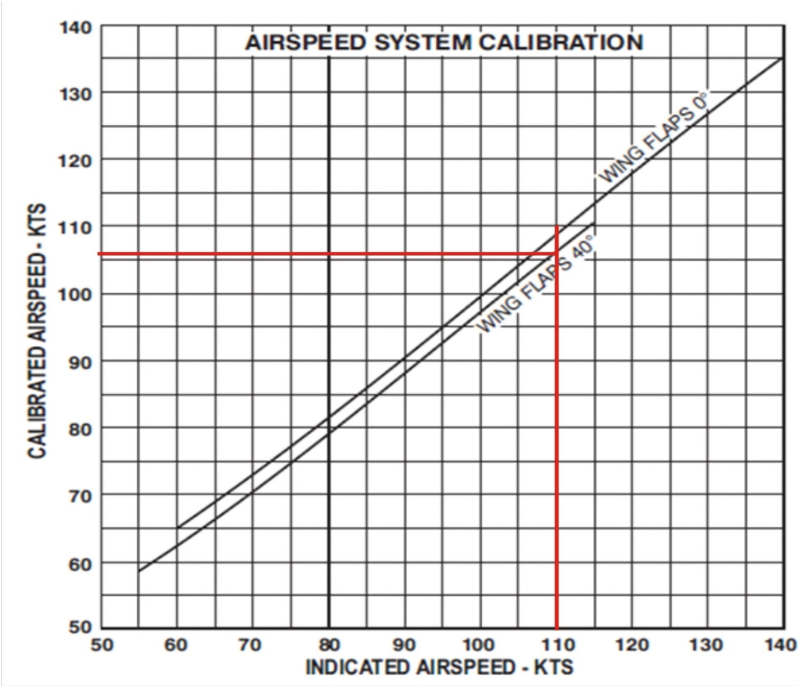
General Graphs

51. To determine CAS you have to use the Airspeed System Calibration graph. All the errors of IAS for different flap settings are corrected by this graph.

Example:

W hat is the CAS if the IAS is 110kts with 40º Flap?

CAS 106kts (see overleaf).

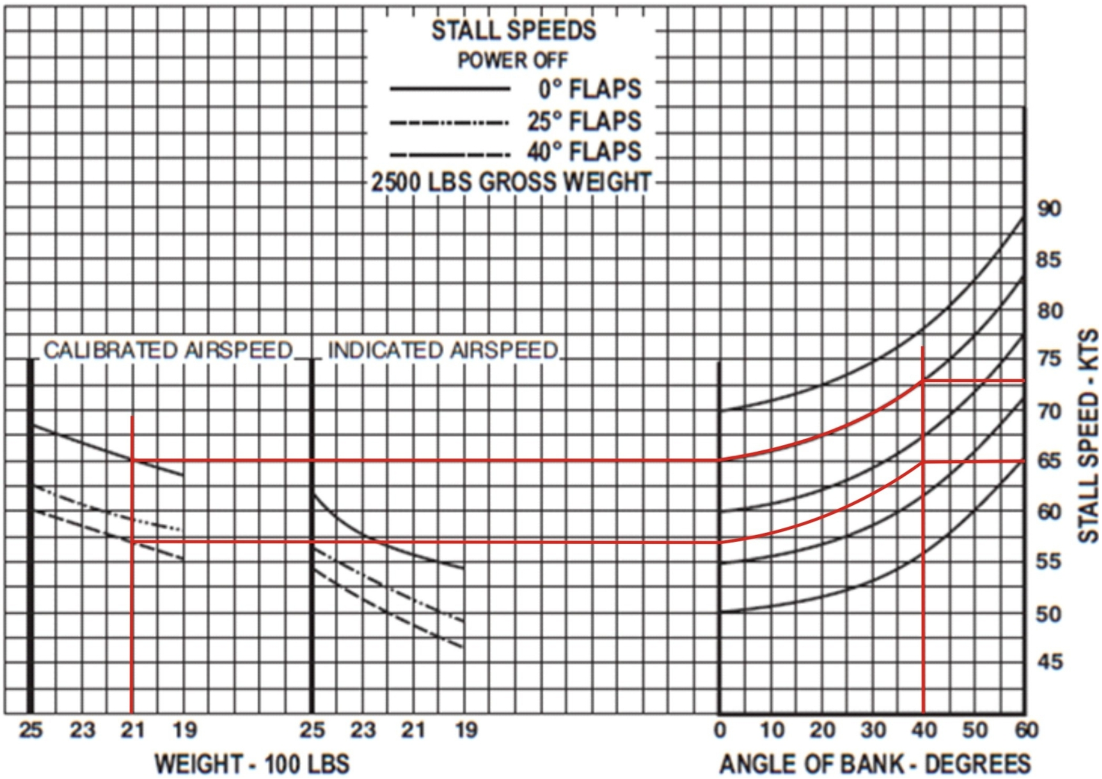


Graph 5.11. Airspeed Calibration

52. Stall speed performance graphs are designed to give an understanding of the speed at which the aircraft will stall in a given configuration. This type of graph will typically take into account the angle of bank and flaps and you can determine the stall speeds for IAS and CAS.

Example:

W hat is the CAS stall speed for 0º and 40º flaps, when the aircraft weighs 2 100lbs at a 40º angle of bank?



Graph 5.12. Stall Speeds

The CAS stall speed for 0º is 73kts and for 40º flaps is 65kts.

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53. For most of the graphs there are tables available to solve performance criteria. Enter the tables with available parameters, interpolate between the parameters for the answers.

Range Performance

54. The ability of an aircraft to convert fuel energy into flying distance is one of the most important items of aircraft performance. In flying operations, the problem of efficient range operation of an aircraft appears in two general forms:

1. To extract the maximum flying distance from a given fuel load.

2. To fly a specified distance with a minimum expenditure of fuel.

55. A common element for each of these operating problems is the specific range; that is, nautical miles (NM) of flying distance versus the amount of fuel consumed. Range must be clearly distinguished from the item of endurance. Range involves consideration of flying distance, while endurance involves consideration of flying time. Thus, it is appropriate to define a separate term, specific endurance.

$$Specific\ Endurance = \frac{Flight\ hours}{Pounds\ of\ fuel}$$

or

$$Specific\ Endurance = \frac{Flight\ hours\ /\ hr}{Pounds\ of\ fuel\ /\ hr}$$

56. Fuel flow can be defined in either pounds or gallons. If maximum endurance is desired, the flight condition must provide a minimum fuel flow. During ground operations or when taking off and climbing, the airspeed is low and fuel flow is high. As airspeed is increased, power requirements decrease due to aerodynamic factors and fuel fl ow decreases. Increases in airspeed come at a cost. Airspeed increases require additional power and fuel flow increases with additional power.

57. Cruise flight operations for maximum range should be conducted so that the aircraft obtains maximum specific range throughout the flight. The specific range can be defined by the following relationship.

$$Specific\ Range = \frac{Nautical\ Miles}{Pounds\ of\ fuel}$$

or

$$Specific\ Range = \frac{NM\ /\ hr}{Pounds\ of\ fuel\ /\ hr}$$

58. If maximum specific range is desired, the flight condition must provide a maximum of speed per fuel flow.

59. The values of specific range versus speed are affected by three principal variables:

1. Aircraft gross weight.

2. Altitude.

3. The external aerodynamic configuration of the aircraft.

60. Specific range is defined as the distance an aircraft will fly per unit fuel, or the amount of fuel required to fly per unit distance.

61. Specific fuel consumption is defined as the amount of fuel used per hour, fuel flow.

HELICOPTER PERFORMANCE

62. Your ability to predict the performance of a helicopter is extremely important. It allows you to determine how much weight the helicopter can carry before takeoff, if your helicopter can safely hover at a specific altitude and temperature, how far it will take to climb above obstacles, and what your maximum climb rate will be. A helicopter's performance is dependent on the power output of the engine and the lift production of the main rotor. Any factor that affects engine and rotor efficiency affects performance. The three major factors that affect performance are density altitude, weight, and wind.

Density Altitude

63. You need to thoroughly understand the terms "high density altitude" and "low density altitude." In general, high density altitude refers to thin air, while low density altitude refers to dense air. Those conditions that result in a high density altitude (thin air)

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are high elevations, low atmospheric pressure, high temperatures, high humidity, or some combination thereof. Lower elevations, high atmospheric pressure, low temperatures, and low humidity are m ore indicative of low density altitude (dense air). However, high density altitudes may be present at lower elevations on hot days, so it is important to calculate the density altitude and determine performance before a flight. One of the ways you can determine density altitude is through the use of graphs designed for that purpose.

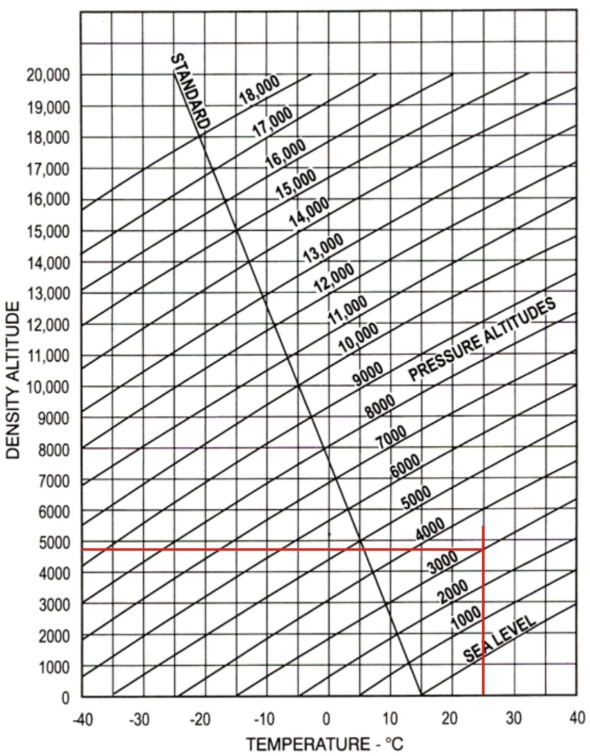
Example:

W hat is the Density Altitude for the following conditions?

Airfield Elevation is 3 000ft
OAT is 25ºC
QNH 1020

64. First correct elevation to pressure altitude, this can be done either with your W hizwheel or mathematics. PA is 2 816ft.

66. Let's determine the density altitude by means of a sample graph.



Graph 5.13. Density Altitude

Density altitude is 4 800ft

You can also determine density altitude by means of your Pathfinder. Go to "Flight" then "Altitude" then "Density Alt" and then enter your pressure altitude and outside air temperature. Density altitude according to the Pathfinder is 4 828ft.

66. Most performance charts do not require you to determine density altitude. Instead it is already built into the performance chart itself. All you have to do is enter the chart with the correct pressure altitude and the temperature.

Weight

67. Lift is the force that opposes weight. As weight increases, the power required to produce the lift needed to compensate for the added weight must also increase. Most performance charts include weight as one of the variables. By reducing the weight of the helicopter, you may find that you are able to safely take off or land at a location that otherwise would be impossible. However, if you are ever in doubt about whether you can safely perform a takeoff or landing, you should delay your takeoff until more favourable density altitude conditions exist. If airborne, try to land at a location that has more favourable conditions, or one where you can make a landing that does not require a hover. In addition, at higher gross weights, the increased power required to hover produces more torque, which means more anti-torque thrust is required.

Wind

68. Wind direction and velocity also affect hovering, takeoff, and climb performance. Translational lift occurs anytime there is relative airflow over the rotor disc. This occurs whether the relative airflow is caused by helicopter movement or by the wind. As wind speed increases, translational lift increases, resulting in less power required to hover. The wind direction is also an important consideration. Headwinds are the most desirable as they contribute most to increase performance. Strong crosswinds and tailwinds may require the use of more tail rotor thrust to maintain directional control. This increased tail rotor thrust absorbs power from the engine, which means there is less power available to the main rotor for the production of lift. Some helicopters even have a critical wind azimuth or maximum safe relative wind chart. Operating the helicopter beyond these limits could

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cause loss of tail rotor effectiveness. Takeoff and climb performance is greatly affected by wind. W hen taking off into a headwind, effective translational lift is achieved earlier, resulting in more lift and a steeper climb angle. W hen taking off with a tailwind, more distance is required to accelerate through translation lift.

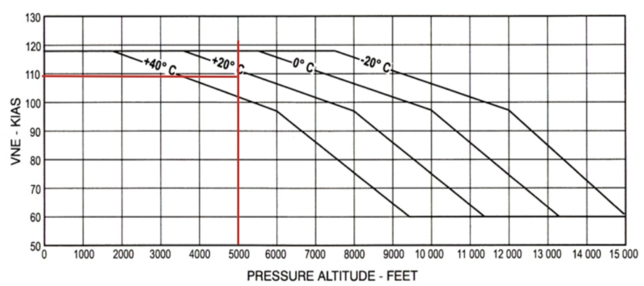
Hovering Performance

69. Helicopter performance revolves around whether or not the helicopter can be hovered. More power is required during the hover than in any other flight regime. Obstructions aside, if a hover can be maintained, a takeoff can be made, especially with the additional benefit of translational lift. Hover charts are provided for in ground effect (IGE) hover and out of ground effect (OGE) hover under various conditions. The “in ground effect” hover ceiling is usually higher than the “out of ground effect” hover ceiling because of the added lift benefit produced by ground effect.

Example:

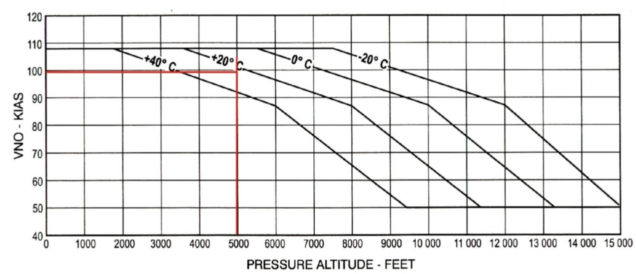
W hat is the maximum weight you can hover IGE with the following conditions?

PA is 5 000ft
OAT is 25ºC



Graph 5.16. Never Exceed Speed

VNE is 109 kts.



Graph 5.17. Normal Operating Speed

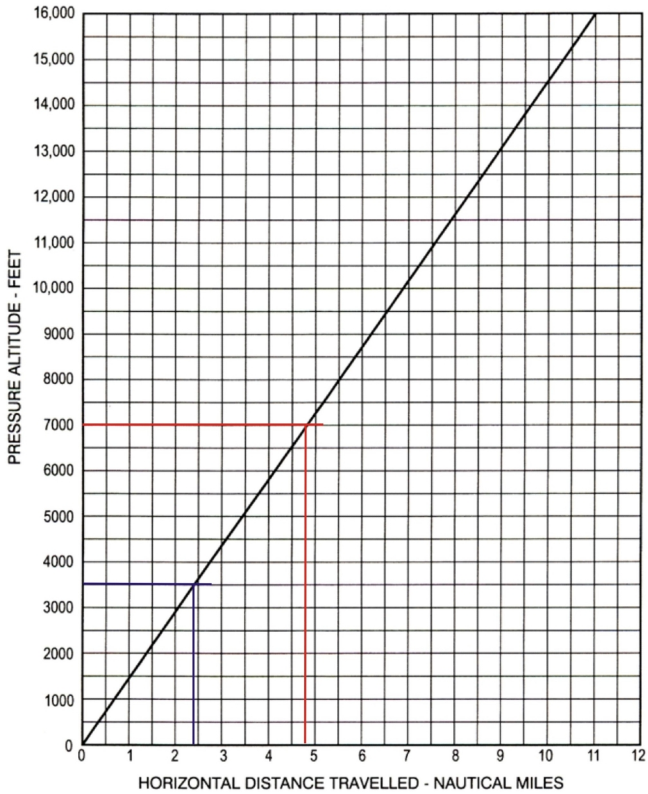
VNO is 99 kts.

70. Autorotation is the state of flight where the main rotor system is being turned by the action of relative wind rather than engine power. It is the means by which a helicopter can be landed safely in the event of an engine failure. In this case, you are using altitude as potential energy and converting it to kinetic energy during the descent and touchdown. You can determine your horizontal distance during autorotation by means of a graph.

Example:

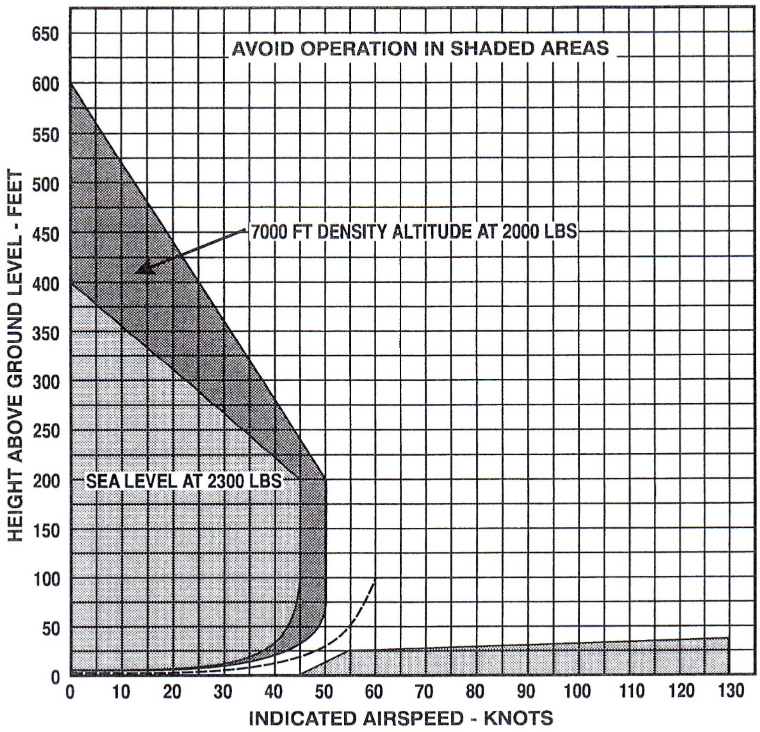
W hat is the horizontal distance you have travelled when doing an autorotation from 7 000ft to 3 500ft?

From 7 000ft to sea level	4.8nm
- From 3 500ft to sea level	2.4nm
= From 7 000ft to 3 500ft	2.4nm



Graph 5.18. Autorotation Performance

71. A height/velocity (H/V) diagram, published by the manufacturer for each model of helicopter, depicts the critical combinations of airspeed and altitude should an engine failure occur. Operating at the altitudes and airspeeds shown within the crosshatched or shaded areas of the H/V diagram may not allow enough time for the critical transition from powered flight to autorotation.



Graph 5.19. Height - Velocity Diagram

WEIGHT AND BALANCE

Introduction

72. W hen it comes to the loading of an aircraft, we must think back to POF where the relationship between Centre of Pressure and Centre of Gravity (CG) was discussed. W e saw there that the two are very close together. If they are moved far apart, the aircraft becomes more difficult to control, and could even become uncontrollable. Similarly, if the wrong one of the two is in front, then the aircraft could become uncontrollable.

73. Think of a see-saw. Place a small child on one end, and a large grown man on the other. If the man were to sit closer to the Datum than the child, it is possible for the child to lift the man. If the child were far enough away from the Datum, the man would not be able to get down again. It has to do with the distance from the Datum, called the Arm, and the Weight of each of the two. Multiply the arm by the weight, and the result is called the Moment.

74. If our adult weighed 200 pounds (I use pounds because the Performance Manuals of all US aircraft do the same), and was sitting 5 feet from the Datum, his moment would be 200 x 5 = 1000 foot/pounds (ft/lb). A child of 50 lb, sitting 20 ft from the Datum would produce the same moment (50 x 20 = 1000). They would be in a state of balance.

75. If the child were to sit a further 10 ft away from the Datum, at 30 ft, the moment would increase to 1500 ft/lb, and the man would stay up there until the child decides to let him down!

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76. Another way for the man to get back into a state of balance would be to increase his weight to 300 lb (300 x 5 = 1500). This is not always possible.

77. Exactly the same thing applies to the loading of an aircraft. Place an item of baggage too far away from the Datum (in this case the CG) and the moment could be too much for the flight controls to correct. If the item of baggage is loaded far enough away from the CG, it does not even have to weigh all that much.

78. It is absolutely imperative that you never attempt to fly any aircraft if the centres of gravity limitations have been exceeded when loading the Aircraft. If you adhere to the placard weight limits of the baggage compartment when loading the Aircraft, you should always be within limits. Placard limits are those specified by the manufacturer in the Aircraft Manual.

79. Remember too, that the floor of your aircraft is not made of cast iron, so be careful of the weight of each single item. A very heavy item of baggage, if it has a very small "footprint", could quite easily cause damage to the baggage compartment floor. Think of the effect of high heels shoes - a small petite woman wearing high heels will produce a greater pressure per unit area than a heavy man with big, flat shoes.

80. Because the majority of the flying that you will be doing during your Private Pilot Licence course will be on the Cherokee 140, these notes will concentrate on the Owner's Handbook and Performance Charts of that Aircraft and the sample graphs from CAA. Once you have mastered the use of the charts and graphs, you will find that the graphs of most light aircraft are very similar. Only the numbers change a bit, the technique stays the same.

Terminology and Definitions

Centre of Gravity

Centre of Gravity (CG) is defined as the position through which the weight of the aircraft acts. The Centre of Gravity is also the point of balance and as such it affects the stability of the aircraft.

Centre of Gravity Limitations

The most forward and most aft position of the CG at which the aircraft is permitted to fly.

Reference Point or Datum

A point designated by the manufacturer on the longitudinal axis (or extension thereof) from which all measurements are taken in the calculation of CG. The Datum is also the reference line from which all th e measurements regarding the position of components are taken. The Datum is sometimes called the "Fulcrum".

Arm

The distance, measured in inches, from the Datum to the point at which the weight of a component acts. All arms aft of the Datum are positive and all arms forward of the Datum are negative.

Flight Station

Flight Station (FS) and Centroid are terms used to indicate a particular position on the fuselage of the aircraft measured from the Datum .

Moment

The turning effect of a weight around the Datum, it is the product of the weight multiplied by the arm.

Aircraft Empty Weight (AEW)

The precise weight of an aircraft when all non removable components are assembled.

Basic Empty Weight (BEW)

The weight of an aircraft with oil, hydraulics and unusable fuel.

Operating Empty Weight (OEW)

The basic empty weight plus crew and catering for a specific flight.

Payload

The payload is considered to be the cargo and the passengers.

Maximum Zero Fuel Weight (MZFW)

The Maximum Zero Fuel W eight is a structural limitation and must never be exceeded. The Zero Fuel W eight is the Operating W eight of an aircraft plus the payload, it is the weight of

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an aircraft with everything loaded except the required fuel for the flight.

Ramp Weight

The Ramp W eight is the maximum weight an aircraft is allowed to taxi.

Maximum Take-Off Weight (MTOW)

This is the maximum weight that an aircraft is allowed to commence the take-off.

Total Fuel

The total fuel consists of the trip fuel, taxi fuel and reserve fuel.

Burn Off (BO) or Trip Fuel

This is the fuel requirement to fly from your departure to your destination.

Weight Schedule

81. There are three factors limiting any take-off, MZFW , MTOW and MLW . W hen calculating the maximum payload for a trip, you first have to calculate the trip and total fuel needed to fly from departure to destination. Because you are not allowed to exceed your MLW , you start your calculations with MLW . Calculate your TOW by adding the trip fuel, if you exceed your MTOW limitation, use the structural limitation figure and carry on with your calculations, if you do not exceed your MTOW limitation, carry on with your calculation with your calculated TOW . Calculate your ZFW by subtracting the total fuel for your flight from the TOW . If you exceed your MZFW limitation, use the structural limitation figure and carry on with your calculations, if you do not exceed your MZFW limitation, carry on with your calculation with your calculated ZFW . Now you can calculate your payload by subtracting the BOW from the calculated ZFW .

82. If the MLW of an aircraft is the same as its MTOW , you start your calculation with MTOW . Subtract the total fuel for the flight from MTOW to determine your ZFW , if you do not exceed your MZW limitation, carry on with your calculation. If you exceed your MZFW limitation, use the structural limitation figure and carry on with your calculations. Now you can calculate your payload by subtracting the BOW from the calculated ZFW .

	WEIGHT SCHEDULE	STRUCTURAL LIMITATION
	Aircraft Empty W eight (AEW)	
+	Unusable Fuel, Oil etc	
=	Basic Empty W eight (BEW)	
+	Crew & Catering	
=	Operating Empty W eight (OEW)	
+	Payload	
=	Zero Fuel W eight (ZFW)	Maximum Zero Fuel Weight (MZFW)
+	Total Fuel	
=	Ramp Weight (RW)	Maximum Ramp Weight (MRW)
-	Taxi Fuel	
=	Take-off W eight (TOW)	Maximum Take-off Weight (MTOW)
-	Burn Off (Trip Fuel)	
=	Landing W eight (LW)	Maximum Landing Weight (MLW)

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Specific Gravity

83. When you have refuelled your aircraft, the amount of fuel loaded will normally be given to you in a unit of volume. When you calculate the performance or weight and balance of an aircraft, you have to use a unit of weight. You thus have to convert the volume of the fuel to the weight of the fuel. The weight or “heaviness” of fuel is measured in terms of the density or the specific gravity of the fuel. Specific gravity is the ratio of the weight of a unit volume of fuel and the weight of an equal volume of water (remember the SG of water is 1).

84. When you convert fuel volume to volume or weight to weight, the conversion factor always remains constant. When converting fuel volume to fuel weight or fuel weight to fuel volume, there is no constant factor, the conversion depends on the density or the SG of the fuel.

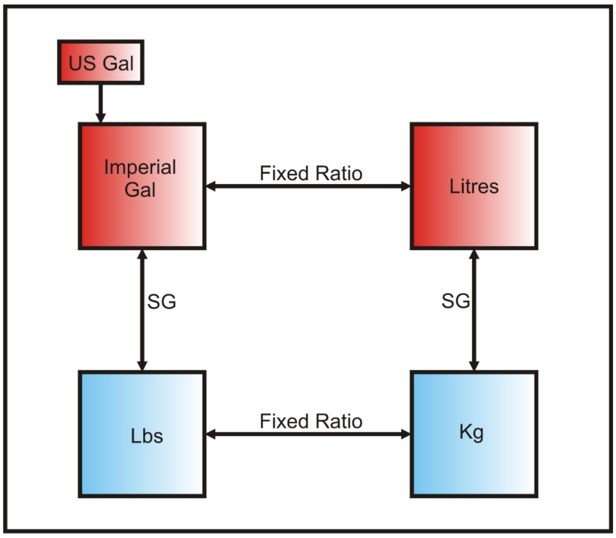

Fig 5.8. Relationship of Weights and Volumes

85. The following conversion factors will come in handy when converting between different units:

1 Imp Gal	=	1.2 US Gal
1 Imp Gal	=	4.54 Litres
1 Imp Gal of H_2O	=	10 Lbs
1 US Gal of H_2O	=	8.33 Lbs
1 Litre of H_2O	=	1 Kg
1 Kg	=	2.205 Lbs

86. Specific gravity is the ratio of the weight of a unit volume of fuel and the weight of an equal volume of water, thus you can use the following formula to your conversions:

$$SG = \frac{Weight\ per\ Unit\ Volume\ of\ Fuel}{Weight\ of\ the\ same\ Volume\ of\ Water}$$

or

$$SG = \frac{Weight}{Weight}\ \frac{Fuel}{Water}\ \frac{Volume}{Volume}$$

87. Remember, you can always convert from water volume to fuel volume or vice versa, volume is volume. A 100 Litres of water is a 100 Litres of fuel. When converting fuel weight to water weight or vice versa, you have to use SG because the specific gravity of water and fuel are not the same, water is heavier than fuel. You can always convert water volume to water weight, or vice versa, but you can never convert fuel volume to fuel weight, or vice versa, directly. You have to divide the fuel weight by the SG to get water weight or multiply the water weight by the SG to get fuel weight.

Example:

You have loaded 600 Litres of fuel with a SG of 0.65, what is the weight in kilograms?

$$SG = \frac{Weight}{Weight}\ \frac{Fuel}{Water}\ \frac{Volume}{Volume}$$

$$0.65 = \frac{Weight}{Weight}\ \frac{Fuel}{Water}\ \frac{600\,L}{600\,L}$$

600L of water is 600Kg of water

$$0.65 = \frac{Weight}{600\,Kg}\ \frac{Fuel}{Water}\ \frac{600\,L}{600\,L}$$

600Kg X 0.65 = 390Kg

$$0.65 = \frac{390\,Kg}{600\,Kg}\ \frac{Fuel}{Water}\ \frac{600\,L}{600\,L}$$

Example:

You have loaded 200 Kg of fuel with a SG of 0.8, what is the amount of gallons you have loaded?

$$SG = \frac{Weight}{Weight}\ \frac{Fuel}{Water}\ \frac{Volume}{Volume}$$

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$$0.8 = \frac{200\,Kg}{Weight}\frac{Fuel}{Water}\frac{Volume}{Volume}$$

200Kg ÷ 0.8 = 250Kg

$$0.8 = \frac{200\,Kg}{250\,Kg}\frac{Fuel}{Water}\frac{Volume}{Volume}$$

250Kg of water is 250L of water

$$0.8 = \frac{200\,Kg}{250\,Kg}\frac{Fuel}{Water}\frac{Volume}{250\,L}$$

250L of water is 250L of fuel

$$0.8 = \frac{200\,Kg}{250\,Kg}\frac{Fuel}{Water}\frac{250\,L}{250\,L}$$

250L of fuel is 55 Imp Gal (66 USG) of fuel

Weight Control

88. Weight is a major factor in Aircraft construction and operation, and it demands respect from all pilots. Excessive weight reduces the efficiency of an aircraft and the safety margin available if an emergency condition should arise. When an aircraft is designed, it is made as light as the required structural strength will allow, and the wings or rotors are designed to support the maximum allowable weight. When the weight of an aircraft is increased, the wings or rotors must produce additional lift and the structure must support not only the additional static loads, but also the dynamic loads imposed by flight manoeuvres. For example, the wings of a 3,000-pound Aircraft must support 3,000 pounds in level flight, but when the Aircraft is turned smoothly and sharply using a bank angle of 60°, the dynamic load requires the wings to support twice this, or 6,000 pounds. Severe uncoordinated manoeuvres or flight into turbulence can impose dynamic loads on the structure great enough to cause failure. The structure of a normal category Aircraft must be strong enough to sustain a load factor of 3.8 times its weight. That is, every pound of weight added to an aircraft requires that the structure be strong enough to support an additional 3.8 pounds. An aircraft operated in the utility category must sustain a load factor of 4.4, and acrobatic category aircraft must be strong enough to withstand 6.0 times their weight. The lift produced by a wing is determined by its aerofoil shape, angle of attack, speed through the air, and the air density. When an aircraft takes off from an airport with a high density altitude, it must accelerate to a speed faster than would be required at sea level to produce enough lift to allow takeoff; therefore, a longer takeoff run is necessary. The distance needed may be longer than the available runway. When operating from a high-density altitude airport, the Pilot's Operating Handbook (POH) or Aircraft Flight Manual (AFM) must be consulted to determine the maximum weight allowed for the aircraft under the conditions of altitude, temperature, wind, and runway conditions.

Effects of Weight

89. Most modern aircraft are so designed that if all seats are occupied, all baggage allowed by the baggage compartment is carried, and all of the fuel tanks are full, the aircraft will be grossly overloaded. This type of design requires the pilot to give great consideration to the requirements of the trip. If maximum range is required, occupants or baggage must be left behind, or if the maximum load must be carried, the range, dictated by the amount of fuel on board, must be reduced. Some of the problems caused by overloading an aircraft are:

a, The aircraft will need a higher takeoff speed, which results in a longer takeoff run.

b. Both the rate and angle of climb will be reduced.

c. The service ceiling will be lowered.

d. The cruising speed will be reduced.

e. The cruising range will be shortened.

f. Manoeuverability will be decreased.

g. A longer landing roll will be required because the landing speed will be higher.

h. Excessive loads will be imposed on the structure, especially the landing gear.

90. The POH or AFM includes tables or charts that give the pilot an indication of the performance

expected for any weight. An important part of careful pre-flight planning includes a check of these charts to determine the aircraft is loaded so the proposed flight can be safely made.

Weight Changes

91. The maximum allowable weight for an aircraft is determined by design considerations. However, the maximum operational weight may be less than the maximum allowable weight due to such considerations as high-density altitude or high-drag field conditions caused by wet grass or water on the runway. The maximum operational weight may also be limited by the departure or arrival airport's runway length. One important pre-flight consideration is the distribution of the load in the aircraft. Loading the aircraft so the gross weight is less than the maximum allowable is not enough. This weight must be distributed to keep the CG within the limits specified in the POH or AFM. If the CG is too far forward, a heavy passenger can be moved to one of the rear seats or baggage can be shifted from a forward baggage compartment to a rear compartment. If the CG is too far aft, passenger weight or baggage can be shifted forward. The fuel load should be balanced laterally: the pilot should pay special attention to the POH or AFM regarding the operation of the fuel system, in order to keep the aircraft balanced in flight. W eight and balance of a helicopter is far more critical than for an Aircraft. With some helicopters, they may be properly loaded for takeoff, but near the end of a long flight when the fuel tanks are almost empty, the CG may have shifted enough for the helicopter to be out of balance laterally or longitudinally. Before making any long flight, the CG with the fuel available for landing must be checked to ensure it will be within the allowable range.

92. Changes of fixed equipment may have a major effect upon the weight of the aircraft. Many aircraft are overloaded by the installation of extra radios or instruments. Fortunately, the replacement of older, heavy electronic equipment with newer, lighter types results in a weight reduction. This weight change, however helpful, will probably cause the CG to shift and this must be computed and annotated in the weight and balance record. Repairs and alteration are the major sources of weight changes, and it is the responsibility of the A&P mechanic or repairman making any repair or alteration to know the weight and location of these changes, and to compute the CG and record the new empty weight and EW CG in the aircraft weight and balance record. The A&P mechanic or repairman conducting an annual or condition inspection must ensure the weight and balance data in the aircraft records is current and accurate. It is the responsibility of the pilot in command to use the most current weight and balance data when operating the aircraft.

Stability and Balance Control

93. Balance control refers to the location of the CG of an aircraft. This is of primary importance to aircraft stability, which determines safety in flight. The CG is the point at which the total weight of the aircraft is assumed to be concentrated, and the CG must be located within specific limits for safe flight. Both lateral and longitudinal balance are important, but the prime concern is longitudinal balance; that is, the location of the CG along the longitudinal. An Aircraft is designed to have stability that allows it to be trimmed so it will maintain straight and level flight with hands off the controls. Longitudinal stability is maintained by ensuring the CG is slightly ahead of the centre of lift. This produces a fixed nose-down force independent of the airspeed. This is balanced by a variable nose-up force, which is produced by a downward aerodynamic force on the horizontal tail surfaces that varies directly with the airspeed.

94. As long as the CG is maintained within the allowable limits for its weight, the Aircraft will have adequate longitudinal stability and control. If the CG is too far aft, tail heavy, it will be too near the centre of lift and the Aircraft will be unstable, and difficult to recover from a stall. If the unstable Aircraft should ever enter a spin, the spin could become flat and recovery would be difficult or impossible.

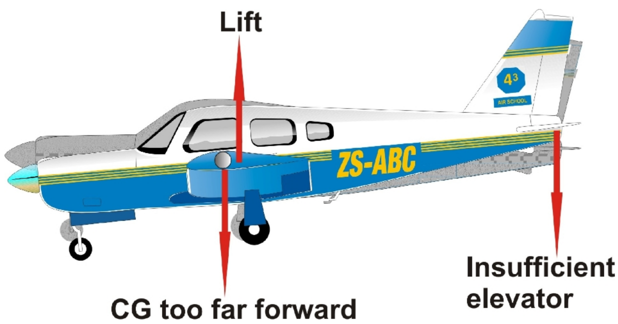

Fig 5.9. CG too far Forward

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95. If the CG is too far forward, nose heavy, the downward tail load will have to be increased to maintain level flight. This increased tail load has the same effect as carrying additional weight; the aircraft will have to fly at a higher angle of attack, and drag will increase.

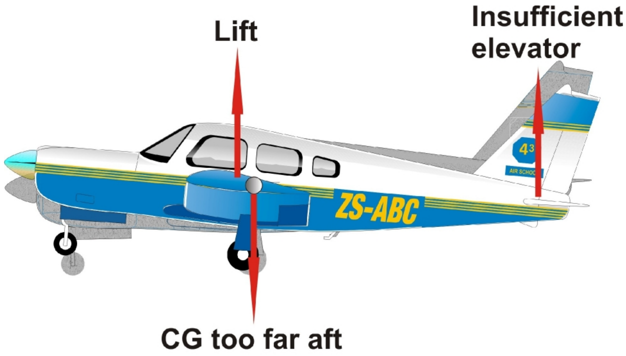

Fig 5.10. CG too far Aft

96. `The lateral balance can be upset by uneven fuel loading or burn off. The position of the lateral CG is not normally computed for an Aircraft, but the pilot must be aware of the adverse effects that will result from a laterally unbalanced condition. This is corrected by using the aileron trim tab until enough fuel has been used from the tank on the heavy side to balance the Aircraft. The deflected trim tab deflects the aileron to produce additional lift on the heavy side, but it also produces additional drag, and the Aircraft flies inefficiently. Helicopters are affected by lateral imbalance more than Aircraft. If a helicopter is loaded with heavy occupants and fuel on the same side, it could be out of balance enough to make it unsafe to fly. It is also possible that if external loads are carried in such a position to require large lateral displacement of the cyclic control to maintain level flight, the fore-and-aft cyclic control effectiveness will be limited.

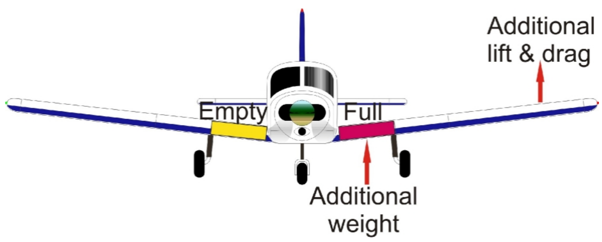

Fig 5.11. Lateral CG

Centre of Gravity

97. Two elements are vital in the weight and balance considerations of an aircraft.

a. The total weight of the aircraft must be no greater than the maximum weight allowed for the particular make and model of the aircraft.

b. The centre of gravity, or the point at which all of the weight of the aircraft is considered to be concentrated, must be maintained within the allowable range for the operational weight of the aircraft.

98. The term arm, usually measured in inches, refers to the distance between the centre of gravity of an item or object and the Datum. Arms ahead of, or to the left of the Datum are negative (-), and those behind, or to the right of the Datum are positive (+). W hen the Datum is ahead of the aircraft, all of the arms are positive and computational errors are minimized. W hen weight is removed from an aircraft, it is negative (-), and when added, it is positive (+). The manufacturer establishes the maximum weight and range allowed for the CG, as measured in inches from the reference line called the Datum. The Datum may be located anywhere the manufacturer chooses; it is often the nose of the aircraft, or the leading edge of the wing, or the engine firewall. The Datum of some helicopters is the centre of the rotor mast, but this location causes some arms to be positive and others negative. To simplify weight and balance computations, most modern helicopters, like Aircraft, have the Datum located at the nose of the aircraft or a specified distance ahead of it.

99. A moment is a force that tries to cause rotation, and is the product of the arm, in inches, and the weight, in pounds. Moments are generally expressed in pound-inches (lb-in) and may be either positive or negative. The weight and balance problems are based on the physical law of the lever. This law states that a lever is balanced when the weight on one side of the fulcrum multiplied by its arm is equal to the weight on the opposite side multiplied by its arm. In other words, the lever is balanced when the algebraic sum of the moments about the fulcrum is zero. This is the condition in which the positive moments (those that try to rotate the lever clockwise) are equal to the negative moments (those that try to rotate it counter-clockwise).

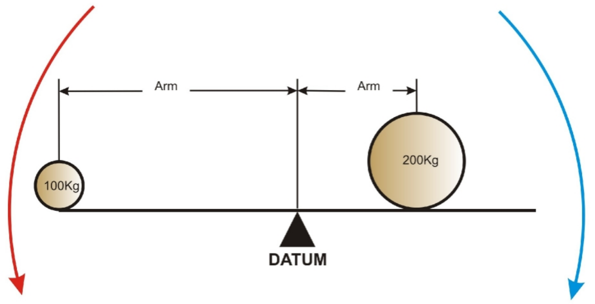

Fig 5.12. Equal Positive & Negative Moments

Determining the CG

100. One of the easiest ways to understand weight and balance is to consider a board with weights placed at various locations. W e can determine the CG of the board and observe the way the CG changes as the weights are moved and may be determined by using these four steps:

1. Measure the arm of each weight in inches from the Datum.

2. Multiply each arm by its weight in pounds to determine the moment in pound-inches of each weight.

3. Determine the total of all weights and of all the moments.

4. Divide the total moments by the total weight to determine the CG in inches from the Datum .

101. To illustrate, assume a weight of 50 K g is placed on the board at a station or point 100 inches from the datum. The downward force of the weight can be determined by multiplying 50 Kg by 100 inches, which produces a moment of 5,000 in-Kg.

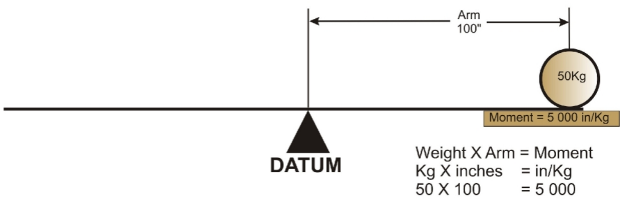

Fig 5.13. Unbalanced

102. To establish a balance, a total of 5,000 in-Kg must be applied to the other end of the board. Any combination of weight and distance which, when multiplied, produces a 5,000 in-Kg moment will balance the board. For example, if a 100-Kg weight is placed at a point (station) 25 inches from the datum, and another 50-Kg weight is placed at a point (station) 50 inches from the datum, the sum of the product of the two weights and their distances will total a moment of 5,000 in-Kg, which will balance the board.

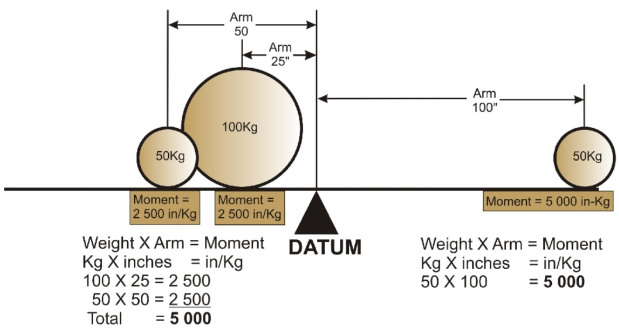

Fig 5.14. Balanced

Loadsheet

103. W e determine the CG of an aircraft by completing a loadsheet.

Example:

From the following data calculate the CG:

Basic Empty W eight 1 350 lbs and a CG of 81.5”.

Pilot and passenger in the front seats at FS 72.8”.

1 X Passenger in the rear seats at FS 110.6”

20 Gal of fuel at a SG of 0.80 at FS 91.0”.

24 lbs of baggage at FS 134.5”.

Average weight of pilot and passengers are 170 lbs.

The Maximum All Up weight of this aircraft is 2 200 lbs

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LOAD SHEET

Item	W eight	Arm	Moment
Basic Empty W eight	1 350	81.5	110 025
Pilot & Passenger @ 170Lbs each	340	72.8	24 752
1 X Passenger @ 170Lbs	170	110.6	18 802
Baggage	24	134.5	3 228
Fuel: SG 0.8 is 200Lbs X .8	160	91.0	14 560
Totals	2 044		171 367

CG = Total Moments divided by total weight

CG = 83.84”

104. The weight and CG limits are published in the aircraft’s manuals. Some aircraft may have different weight and CG limits for operations in different categories:

Normal Category

Manoeuvres used in normal flight with less than 60E angle of bank. Aerobatic manoeuvres (including spins) are not permitted.

Utility Category

All manoeuvres in the normal category as well as spins and steep turns with an angle of bank in excess of 60 E.

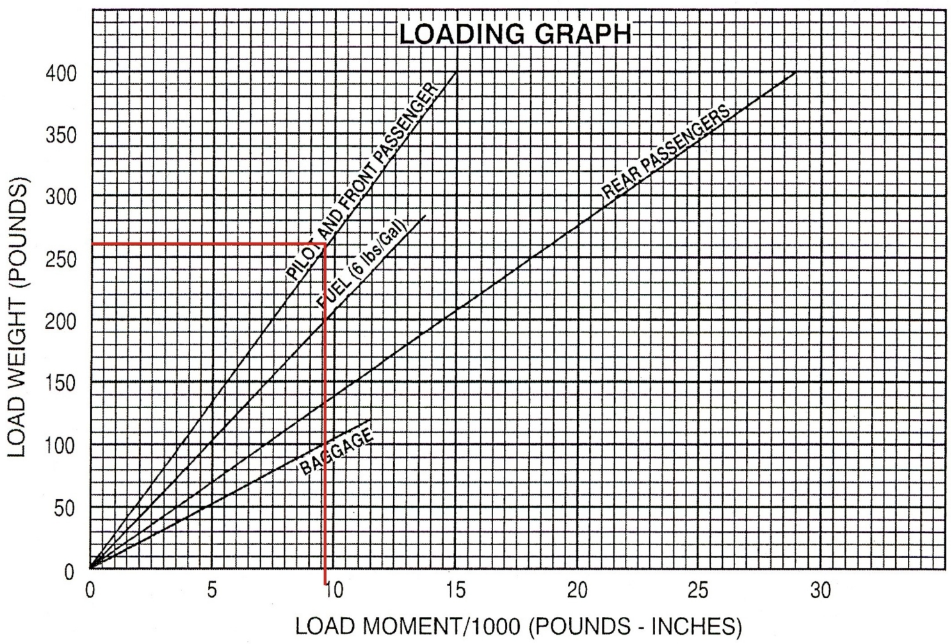
Aerobatic Category

All manoeuvres in the previous categories as well as aerobatic manoeuvres according to the aircraft’s manual.

105. Another method for determining the loaded weight and CG is the use of graphs provided by the manufacturers.

Example:

If the pilot and front passenger weighs 260 Lbs, what is the Load Moment/1 000?



Graph 5.20. Loading Graph

The load moment/1 000 = 9.6

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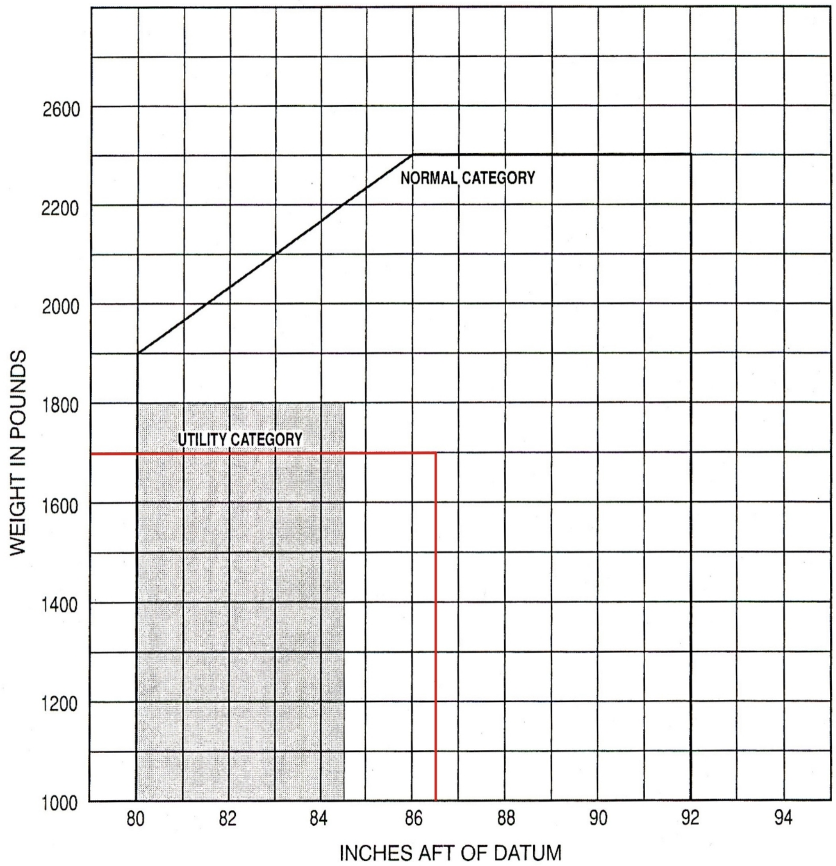
106. If you have calculate you CG as 86.5" aft of the Datum at a weight of 1 700 Lbs, you may only operate in the normal category according to Graph 3.21.



Graph 3.21. CG Envelope

Helicopter Weight & Balance

107. It is vital to comply with weight and balance limits established for helicopters. Operating above the maximum weight limitation compromises the structural integrity of the helicopter and adversely affects performance. Balance is also critical because on some fully loaded helicopters, centre of gravity deviations as small as three inches can dramatically change a helicopter's handling characteristics. Taking off in a helicopter that is not within the weight and balance limitations is unsafe. Helicopter performance is not only affected by gross weight, but also by the position of that weight. It is essential to load the aircraft within the allowable centre of gravity range specified in the rotorcraft flight manual's weight and balance limitations.

108. The centre of gravity is defined as the theoretical point where all of the aircraft's weight is considered to be concentrated. If a helicopter was suspended by a cable attached to the centre-of-gravity point, it would balance like a teeter-totter. For helicopters with a single main rotor, the CG is usually close to the main rotor mast. Improper balance of a helicopter's load can result in serious control problems. The allowable range in which the CG may fall is called the "CG range." The exact CG location and range are specified in the rotorcraft flight manual for each helicopter. In addition to making a helicopter difficult to control, an out-of-balance loading condition also decreases manoeuvrability since cyclic control is less effective in the direction opposite to the CG location.

109. You can recognize CG forward of the forward limitation when coming to a hover following a vertical takeoff. The helicopter will have a nose-low attitude, and you will need excessive rearward displacement of the cyclic control to maintain a hover in a no-wind condition. You should not continue flight in this condition, since you could rapidly run out of rearward cyclic control as you consume fuel. You also may find it impossible to decelerate sufficiently to bring the helicopter to a stop.

In the event of engine failure and the resulting autorotation, you may not have enough cyclic control to flare properly for the landing.

110. You can recognize the aft CG condition when coming to a hover following a vertical takeoff. The helicopter will have a tail-low attitude, and you will need excessive forward displacement of cyclic control to maintain a hover in a no-wind condition. If there is a wind, you need even greater forward cyclic.

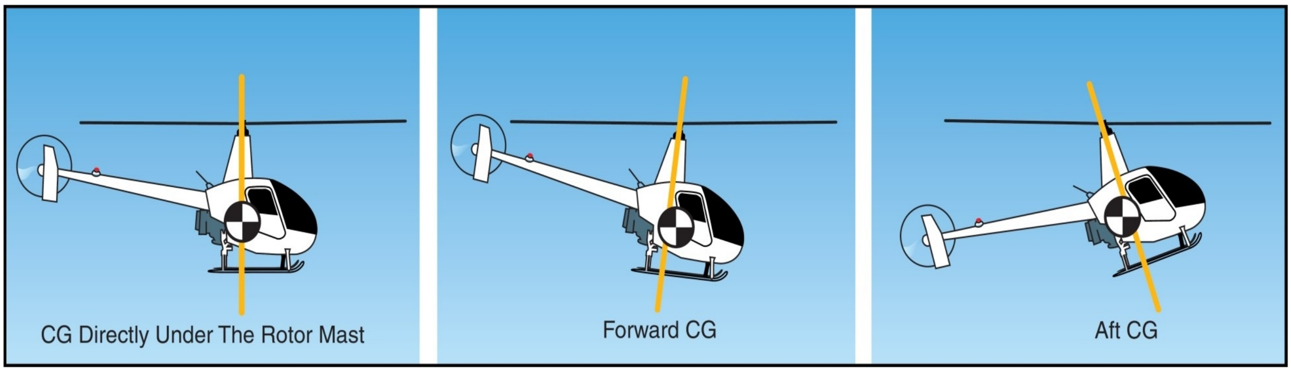


Fig 5.15 Helicopter CG

Lateral Balance

111. For most helicopters, it is usually not necessary to determine the lateral CG for normal flight instruction and passenger flights. This is because helicopter cabins are relatively narrow and most optional equipment is located near the centre line. However, some helicopter manuals specify the seat from which you must conduct solo flight. In addition, if there is an unusual situation, such as a heavy pilot and a full load of fuel on one side of the helicopter, which could affect the lateral CG, its position should be checked against the CG envelope. If carrying external loads in a position that requires large lateral cyclic control displacement to maintain level flight, fore and aft cyclic effectiveness could be dramatically limited.

Determining the CG

112. W hen determining whether your helicopter is properly loaded, you must answer two questions:

1. Is the gross weight less than or equal to the maximum allowable gross weight?

2. Is the centre of gravity within the allowable CG range, and will it stay within the allowable range as fuel is burned off?

113 To answer the first question, just add the weight of the items comprising the useful load (pilot, passengers, fuel, oil, if applicable, cargo, and baggage) to the basic empty weight of the helicopter. Check that the total weight does not exceed the maximum allowable gross weight. To answer the second question, you need to use CG or moment information from loading charts, tables, or graphs in the helicopter flight manual. Then using one of the methods described below, calculate the loaded moment and/or loaded CG and verify that it falls within the allowable CG range shown in the rotorcraft flight manual.

114. Balance is determined by the location of the CG, which is usually described as a given number of inches from the reference Datum. The horizontal reference Datum is an imaginary vertical plane or point, arbitrarily fixed somewhere along the longitudinal axis of the helicopter, from which all horizontal distances are measured for weight and balance purposes. There is no fixed rule for its location. It may be located at the rotor mast, the nose of the helicopter, or even at a point in space ahead of the helicopter.

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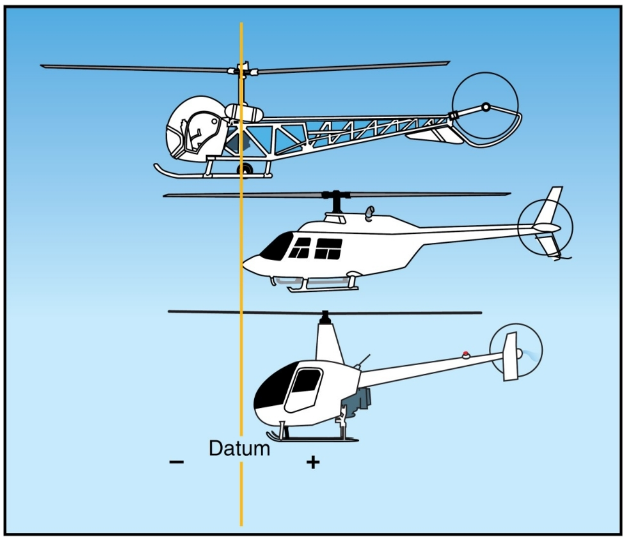

Fig 5.16. Datum Lines

115. The lateral reference Datum, is usually located at the centre of the helicopter. The location of the reference Datum's is established by the manufacturer and is defined in the rotorcraft flight manual.

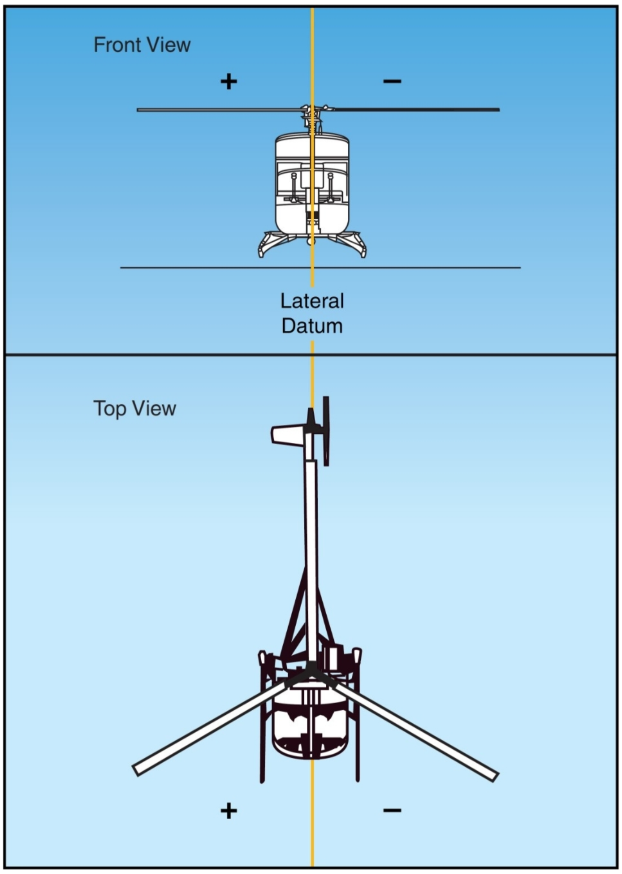

Fig 5.17. Lateral Datum

116. We determine the CG of a helicopter by completing a loadsheet.

Example:

From the following data calculate the CG:

Basic Empty Weight 1 350Lbs and a of CG 81.5".

Pilot and passenger in the front seats at FS 72.8".

1 X Passenger in the rear seats at FS 110.6"

20 Gal of fuel at a SG of 0.80 at FS 91.0".

24Lbs of baggage at FS 134.5".

Average weight of pilot and passengers are 170Lbs.

The Maximum All Up weight of this helicopter is 2 500Lbs

LOADSHEET

Item	Weight	Arm	Moments
Basic Empty Weight	1350	111	110025
Pilot & Fwd Pas @ 170Lbs	340	52.5	24752
Fwd Baggage	75	48	3600
2 X aft Pas @ 160Lbs & 80Lbs Baggage	420	110	46200
ZFW	2185		184577
Main Fuel	150	110	16500
Aux Fuel	100	112	11150
Totals	2435		212227

CG = Total Moments divided by total weight

CG = 87.16"

117. Another method for determining the loaded weight and CG is the use of graphs provided by the manufacturers.

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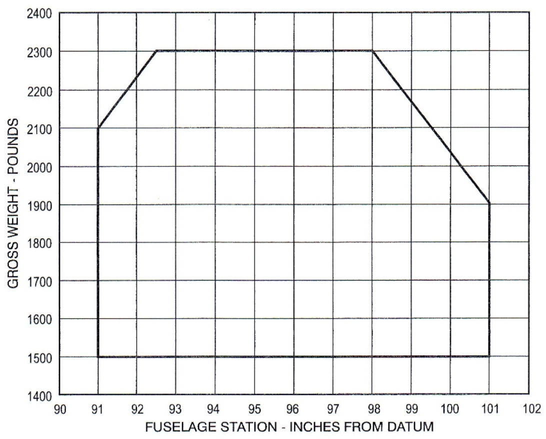

Fig 5.22. Helicopter Longitudinal CG Graph

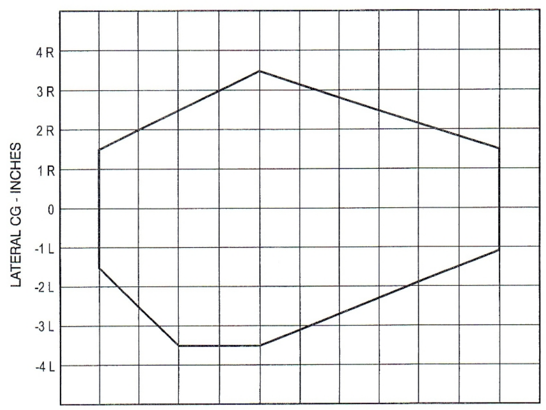

Fig 5.23. Helicopter Lateral CG Graph

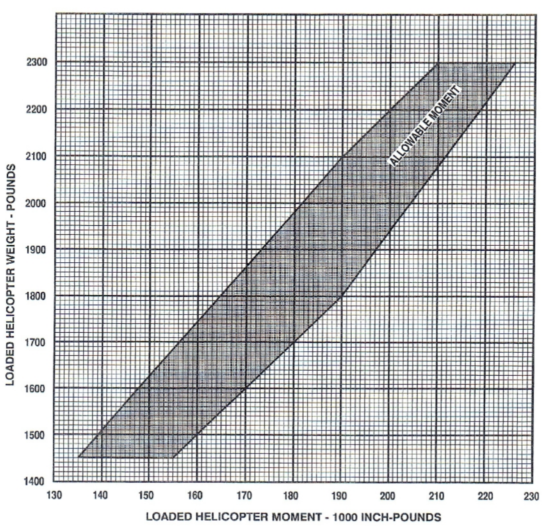

Fig 5.24. Moments vs Weight

Weight Shift, Removal & Addition

118. One common weight and balance problem involves moving passengers from one seat to another or shifting baggage or cargo from one compartment to another to move the CG to a desired location. This problem can be solved by using the basic weight and balance equation:

$$\frac{\text{Weight shifted}}{\text{Total weight}} = \frac{\text{Change in CG}}{\text{Dist weight is shifted}}$$

119. This equation can be rearranged to find the distance a weight must be shifted to give a desired change in the CG location:

$$\text{Dist weight is shifted} = \frac{\text{Total weight } X \text{ Change in CG}}{\text{Weight shifted}}$$

120. This equation can also be rearranged to find the amount of weight to shift to move the CG to a desired location:

$$\text{Weight shifted} = \frac{\text{Total weight } X \text{ Change in CG}}{\text{Dist weight shifted}}$$

121. It can also be rearranged to find the amount the CG is moved when a given amount of weight is shifted:

$$\text{Change in CG} = \frac{\text{Weight shifted } X \text{ Dist weight shifted}}{\text{Total weight}}$$

122. Finally, this equation can be rearranged to find the total weight that would allow shifting a given amount of weight to move the CG a given distance:

$$\text{Total weight} = \frac{\text{Weight shifted } X \text{ Dist weight shifted}}{\text{Change in CG}}$$

Example:

A passenger weighing 170Lbs gets up from his seat at FS 290 and moves to a seat at FS 110 in an aircraft weighing 12 000Lbs. W hat is the effect on CG?

$$\text{Change in CG} = \frac{\text{Weight shifted } X \text{ Dist weight shifted}}{\text{Total weight}}$$

$$\text{Change in CG} = \frac{170 \; X \; (290'' - 110'')}{12000}$$

$$\text{Change in CG} = 2.55'' \text{ Forward}$$

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123. Problems regarding weight added or removed can be solved by using the following equation:

$$Change\ in\ CG = \frac{Weight\ added\ (removed)\ X\ Dist\ between\ weight\ CG\ \&\ old\ CG}{New\ total\ weight}$$

Example:

A paratrooper weighing 200Lbs jumps from the rear cargo door, FS150, the aircraft weighed 4 600Lbs wit a CG of 100" before the jump. W hat is the change of the CG of the aircraft?

$$Change\ in\ CG = \frac{Weight\ added\ (removed)\ X\ Dist\ between\ weight\ CG\ \&\ old\ CG}{New\ total\ weight}$$

$$Change\ in\ CG = \frac{200\ X\ (150" - 100")}{4600 - 200}$$

$$Change\ in\ CG = \frac{10000}{4400}$$

$$Change\ in\ CG = 2.27"\ Forward$$

124. W hen you are required to determine the maximum load that can be loaded at a specific FS, the following equation can be used:

$$Weight\ to\ be\ added = \frac{Original\ weight\ X\ Difference\ between\ desired\ CG\ \&\ actual\ CG}{Dist\ between\ loading\ FS\ \&\ desired\ CG}$$

Example

The original load of an aircraft is 12 000Lbs with a CG of 193". W hat is the load that can be added at FS 325 not to exceed the CG limit of 196.3"?

$$Weight\ to\ be\ added = \frac{Original\ weight\ X\ Difference\ between\ desired\ CG\ \&\ actual\ CG}{Dist\ between\ loading\ FS\ \&\ desired\ CG}$$

$$Weight\ to\ be\ added = \frac{12000\ X\ (196.3" - 193")}{325" - 196.3"}$$

$$Weight\ to\ be\ added = \frac{39600}{128.7}$$

$$Weight\ to\ be\ added = 307.69\ Lbs$$

Solution by Table

125. The easiest way to calculate a weight shift is to subtract the weight and moment from the FS it is shifted from and add the weight and moments at the FS it has been shifted to. W eight and moments can be added or subtracted but Arm or FS's can not be added or subtracted. Remember, weight X arm = moments and that the CG is calculated by the total moments divided by the total weight

Example:

Shortly before take-off a passenger, weighing Lbs, moves from FS 259 to FS 315. Before the transfer the aircraft weight was 12 200Lbs and its CG was 100". How many inches aft does the CG moves?

Item	Weight	Arm	Moment
Aircraft	12 200 Lbs	100"	1 220 000 In/Lbs
Passenger	- 170 Lbs	259"	- 44 030 In/Lbs
Passenger	+ 170 Lbs	315"	+ 53 550 In/Lbs
Total	12 200 Lbs	100.78"	1 229 520 In/Lbs

The CG moved 0.78 inches aft.

Floor Loading

126. The floor loading may be defined as the physical bearing strength of the aircraft floor. It is an expression of maximum weight that can be loaded per surface area on the floor. Remember the formulas to calculate area.

$$Area = Length\ X\ Width$$

a. The area of a rectangular surface is calculated by using the formula:

$$Area = \pi r^2$$

b. The area of a circular surface is calculated by using the formula:

c. Care should be taken to keep all units of measurement the same.

127. Problems regarding floor loading can be solved

$$Floor\ loading = \frac{Maximum\ weight\ on\ floor}{Area\ on\ floor}$$

using the equation:

Example:

What weight can be loaded on a pallet with dimensions 24” by 24”? The weight of the pallet and tie downs is 100Lbs and the floor loading of the aircraft is 200Lbs per square foot.

$$200\ Lbs\ per\ Sq\ /\ Ft = \frac{Maximum\ weight\ on\ floor}{4\ Ft\ /\ Sq}$$

$$Maximum\ weight\ on\ floor = 200\ Lbs\ per\ Sq\ /\ Ft\ X\ 4\ Ft\ /\ Sq$$

$$Maximum\ weight\ on\ floor = 800\ Lbs$$

$$Weight\ on\ pallet = 700\ Lbs$$

(Remember there is a difference between “square feet” and “feet square”)

Aircraft Performance

128. Refer to the Meteorology chapter regarding Icing, Rain, condition of the airframe, wake turbulence and windshear. Refer to the Principles of Flight chapter regarding aquaplaning.

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TYPICAL EXAM QUESTIONS

Here are some examples, the first one is a simple calculation.

A loaded aircraft's CG is 91.0", weight 2400 lbs. A passenger weighing 160 lbs located in a front seat (arm 77.8") changes place with a passenger weighing 100 lbs located in a rear seat (arm 116.6"), the pilot loads an additional 50 lbs of fuel (arm 93.0”). The new CG is:-

a. 92.0"
b. 89.3"
c. 81.2"
d. 96.5"

Answer and explanation:

To solve this problem you have to do three calculations. Two weight shift problems, the two passengers changing seats, and a weight add problem, the additional fuel. W e solve these problems by means of the different equations of the CG formula.

Passenger 1:

$$Change\,in\,CG = \frac{Weight\ shifted\ X\ Dist\ weight\ shifted}{Total\ weight}$$

$$Change\,in\,CG = \frac{160lbs\ X\ (116.6" - 77.8")}{2400lbs}$$

$$Change\,in\,CG = \frac{160lbs\ X\ 38.8"}{2400lbs}$$

$$Change\,in\,CG = 2.59"$$

Passenger 2:

$$Change\,in\,CG = \frac{Weight\ shifted\ X\ Dist\ weight\ shifted}{Total\ weight}$$

$$Change\,in\,CG = \frac{100lbs\ X\ 38.8"}{2400lbs}$$

$$Change\,in\,CG = 1.62"$$

The change in CG caused by passenger “1" was 2.59" backwards and by passenger “2" 1.62" forward, the total change is therefore 2.6" - 1.6" = 0.97" backwards. The new CG, before we load the extra fuel, is now 91.97"

Another method is to use the difference in weight between the two passengers and use that as weight shifted, you will get the same answer.

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Fuel:

$$Change\ in\ CG = \frac{Weight\ added\ \ X\ Dist\ between\ weight\ CG\ \&\ old\ CG}{New\ total\ weight}$$

$$Change\ in\ CG = \frac{50\,lbs\ X\ (93.0" - 92.0")}{2450lbs}$$

$$Change\ in\ CG = \frac{50\ X\ 1}{2450}$$

$$Change\ in\ CG = 0.02"$$

The new CG will therefore be 0.02" backwards, 91.97" + 0.02 = 91.99"

The answer is therefore “a”.

The second question is an example of plain theoretical fact.

2. The presence of a stopway :-

a. W ill affect the landing distance available.
b. W ill not affect the landing distance available.
c. Is not used for emergencies.
d. W ill affect the take-off run available.

Answer and explanation:

A stopway is an extension of the runway that has the same strength and coefficient as the runway. It is only allowed to be used during an emergency and not for normal operations. It therefore can not have an affect on either take-off run or landing distance available.

The answer is therefore “b”.

The third type of question relates to the practical application of facts.

3. In order to avoid the wake turbulence when landing behind a heavy aircraft which has just landed, a lighter aircraft should:-

a. Attempt to land before the point at which the heavy aircraft landed.
b. Attempt to land at the same point at which the heavy aircraft landed.
c. Attempt to land after the point at which the heavy aircraft landed.
d. Don’t attempt to land.

Answer and explanation:

Wake turbulence is caused by the movement of aircraft through the air, the larger and heavier the aircraft the stronger the wake turbulence it produces. By staying above the aircraft’s approach path in front of you and aiming

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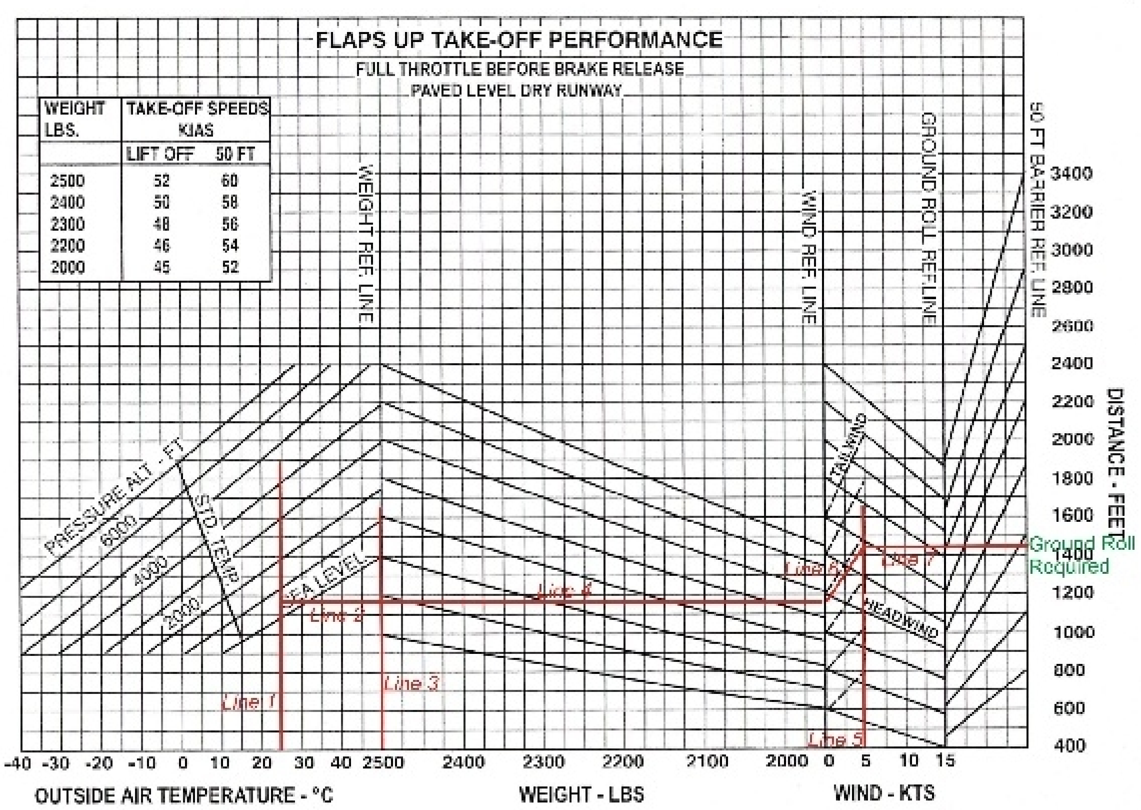
to touch down well beyond its touchdown point, you will avoid its wake turbulence.
The answer is therefore “c”.

The fourth type of question is the interpolation of performance graphs.

4. With reference to Figure 1-3: Flaps Up Take-off Ground Roll. Airfield elevation 650 ft, QNH 1018, OAT +25°C, weight 2500 lbs, 5 kts tailwind. The ground roll required is approximately:-

- a. 1 540ft.
- b. 1 650ft.
- c. 1 450ft.
- d. 1 540ft.

Answer and explanation:
Before you enter the graph, you have to calculate your pressure altitude first, this you can solve by using your pathfinder, pressure altitude is 521ft.



Start with temperature, line1, then pressure altitude, where the two cross, horizontal to your weight reference line, line 2. Draw in your weight line, line 3, it is on the reference line. Draw a line horizontal to your wind reference line, line 4. Draw in your 5 kts tailwind line, line 5. From where line 4 meets the wind reference line, follow the guide line until it crosses line 5, now horizontal across to read your ground roll required.
The answer is therefore “c”.

Try the following questions using the processes prescribed in the preceding questions.

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1. Runway length 1150 metres, stopway 30 metres, displaced threshold 25 metres. The landing distance available is:-

a. 1175
b. 1125
c. 1150
d. 1180

2. With reference to the 25° Flaps Take-off Performance graph. Pressure altitude 4000 ft, temperature +20°C, 5 kts headwind, take-off distance available 2 000 ft. The maximum weight at which take-off can be made is approximately:-

a. 2250lbs
b. 2440lbs
c. 2150lbs
d. 2400lbs

3. With reference to the Best Power Mixture Range. Pressure altitude 10 500 ft, temperature ISA, 55% power. The range with no reserve is approximately:-

a. 700nm
b. 600nm
c. 710nm
d. 685nm

4. The floor loading of an aircraft is 28 kg/m^2. W hat is the weight that a pallet weighing 4 kg and measuring 1.8 x 2.4 can carry?

a. 121 kg
b. 107.5 kg
c. 117 kg
d. 101.5 kg

5. Runway 01 threshold elevation 1275 feet, Runway 19 threshold elevation 1365 feet, Runway length 1078 m. W hat is the slope of Runway 19?

a. 8.34% Downhill
b. 2.55% Downhill
c. 8.34% Uphill
d. 2.55% Uphill

6. Upon landing, an aircraft encounters a sudden increase in headwind component. The aircraft would tend to :

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a. Overshoot

b. Undershoot

c. Experience no change in it's flight-path

7. Maximum Zero-Fuel weight (MZFW) is:

a. Basic Empty weight plus un-usable fuel and full oil.

b. Basic Empty weight plus un-usable fuel, full oil, crew, payload and trip fuel.

c. Basic Empty weight plus un-usable fuel, full oil, crew, payload trip- and taxi fuel.

d. Basic Empty weight plus un-usable fuel, full oil, crew and payload.

8. W hen approaching a wet runway to land one can expect :

a. The landing distance to decrease.

b. The landing distance to increase.

c. The landing distance to remain the same.

9. With reference to the AIRSPEED SYSTEM CALIBRATION graph. W hat will the CAS be with 40% flap at 106 kts IAS

a. 100

b. 107

c. 100

d. 105

10. With reference to STALL SPEEDS (Graph 2). Aircraft weight 2250 lbs, 25° flaps on the CAS graph with an angle of bank of 30°, what would the stall speed be?

a. 59

b. 61

c. 67.

d. 77

ANSWERS

1	2	3	4	5	6	7	8	9	10
b	a	d	c	b	a	d	b	c	a

.

ANSWERS EXPLAINED

1. Stopway is not part of the equation as it may only be used during an emergency, not for normal operations. W hen approaching to land, you must be 50' above the threshold, in this case 50' above the displayed threshold. You must thus subtract the displayed threshold from the runway length.

2. Again, ensure that you are using the correct graph, check and recheck the heading of the graph with parameters given. Draw a vertical line on the 20ºC line until it crosses the 4 000ft PA line. W here the two cross, draw a horizontal line until it crosses the weight reference line. Following the guide lines, draw a line to the right. Now we start from the other end of the graph. TODA is 2 000ft, from the 2 000ft mark at the end of the graph, follow the guideline to the ground roll reference line. Draw a vertical line on the 5kts wind line. Draw a horizontal line from the ground roll reference line until it cross the 5kts wind line. Follow the guideline for a headwind until it crosses the wind reference line. Draw a horizontal line from the wind reference line to the left. W here the two lines cross, draw a line vertically down, read off the MTOW for these parameters. The MTOW for TODA is 2 250lbs. Refer to para 27 for a full explanation regarding MTOW using TODA and TORA.

3. Ensure that you are using the correct graph, check and recheck the heading of the graph with parameters given. It is ISA condition, W here the standard temperature (ISA) line cross the 10 540ft pressure altitude line, is our starting point. Draw a horizontal line to the right until it crosses the range with no reserves 55% power line, draw a line vertically down, range is 710nm.

4. With the formula substitute $28 = x/ 4.32m^2$ and by simple cross-multiplication you get the answer remember to subtract the pallet weight of 4 Kg. The answer is 117 Kg.

5. This one is tricky. Firstly get all measurements in the same units. Convert runway length to feet. Then deduct the smaller threshold elevation from the larger one and divide it by the runway length. Multiply by 100 to get a percentage. Determine which direction is higher or lower and select the correct answer. A simple drawing prevents mistakes!!
Thus 1078m equals 3537' and the difference in elevation is 90'. 90/3537 x 100 = 2.55%. To determine if it is up-slope or down-slope check for which runway they require the slope and see if it is higher or lower than the other one. In this case for runway 19 it is down-slope.

6. The implication of an increase in headwind component is that the RAM air that gives you your ASI reading increases. This would create an increase in airspeed and you would compensate by pulling back on your control stick to counter-act this. Therefore the aircraft would gain height and you would overshoot.

7. As the name ZERO FUEL W EIGHT implies, it includes all parameters EXCLUDING USABLE fuel.

8. You would expect the landing distance to increase because you can not apply your brakes as normal, You have to make more use of aerodynamic braking ie increase the drag as much as possible.

9. Simply draw a line up at the IAS of 106 to the reference line of 40° flap and read off the CAS as 103.

10. Enter the graph on the left bottom at the CAS side at weight 2250 lbs op to the 25° flaps line. Move across

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horizontally to the reference line. Draw a vertical line upwards from the angle of bank at 30° and follow the guidelines until the 2 intersect. Now move horizontally across to get the stall speed of 65 kts.

The following questions do not offer any options, There may be more than one correct answer, so use your knowledge and the Flight Planning and Performance text to find possible solutions.

1. W hat is Maximum Ramp W eight?

2. On the 25° flap Take-off Performance graph: Elevation 2380, QNH 1009, temp ISA +5 and aircraft weight 2250 lbs with a 7 kts HW C, what is the ground roll and distance over the 50' barrier respectively?

3. During approach to land you encounter a sudden drop in TW C. W hat can you expect regarding your flight path?

4. W hat speeds does V_x V_y, V_{le} and V_{lo} stand for respectively?

5. Pressure altitude 9500, temp -7°C. W hat would the BEST POW ER MIXTURE RANGE graph be with reserves at 65% power?

6. W hat would the best GLIDING RANGE graph be from pressure altitude 11000' to an airfield elevation 2800', QNH 1023?

7. On the AIRSPEED CORRECTION TABLE if your KIAS is 87 kts, what would your KCAS be for 10° flaps?

8. Airfield Pressure Altitude 1800ft, QNH 1023. The elevation is:-

9. On the MAXIMUM RATE OF CLIMB Table:- aircraft weight 2400 lbs, pressure altitude 5000' and temp ISA +7°. W hat is your maximum rate of climb in fpm?

10. W hat is the floor-loading of a pallet with an area of 2.5 feet^2 and a weight of 115lbs in kg/m^2?

11. On the LANDING DISTANCE AVAILABLE table: Aircraft weight 2400 lbs, pressure altitude 3500, temp ISA +9, HW C 7 kts and a grass runway. W hat would the distance be to clear 50'?

12. Would an aircraft with a weight of 1620 lbs and a COG of 84.1'' be able to spin according to the CG ENVELOPE graph?

13. On the FLAPS UP TAKE OFF PERFORMANCE graph:- pressure altitude 5500', temp ISA, 50' barrier distance available with a headwind of 12 kts is 1 950', what is the maximum weight possible to take off with?

14. An aircraft is to fly from A to B, distance 235 nm, TAS 90 kts, tailwind 5 kts, cruise fuel flow 8.5 USG/Hr, assume 3 USG is unusable and the reserve fuel requirement is 9 USG. The total fuel required is:-

15. W hen taking off behind a heavy aircraft that just landed, where should a small aircraft rotate?

16. An aircraft flies 3.5 nm/lb. If the fuel flow for the trip is 8.7 USG/HR (SG 0.72) and you have a tailwind component of 7 kts, what is your TAS?

17. A loaded aircraft's COG is 89.6'',weight 2350 lbs. A passenger weighing 150 lbs (arm 78.2'') changes places with a passenger weighing 110 lbs (arm 114.5''). W hat will the new CG be?

18. If the pilot in Q17 added on 245 kg of fuel (arm 190.5'), what will the new COG be?

19. Define Basic Empty W eight.

20. W hat does the speeds V_a and V_{ne} represent?

21. With 38 USG of fuel and a fuel-flow of 8.6 USG/hr allowing 7 USG as diversion, what is the endurance of the aircraft?

22. Upon landing you suddenly experience a drop in tailwind. How would this affect your flight-path?

23. If you land behind a landing larger aircraft, where should your touch-down point be?

24. How do you determine the COG of an aircraft?

25. Aircraft weight 2500 lbs, COG 91.3'' :- if you burn off 435 lbs of fuel (arm 87'')during flight what would the new COG be?

26. At what V-speed should you fly to attain maximum vertical distance in the least horizontal distance?

27. W hat are the symptoms of carburettor icing?

28. W hat are the 3 categories of COG with regards to Mass and Balance?

29. Can a clearway be part of TODA?

30. W hen doing graphs and you work from left to right, what process must be followed to reach the required answer?

Answers to the straight questions.

1. Maximum Ramp W eight is Maximum All Up W eight AND taxi- fuel.

2. Ground roll is 600' and over 50' barrier is 1000'.

3. You will undershoot.

4. Vx - Best angle of climb.
   Vy - Best rate of climb.
   Vfe - Maximum speed with flaps extended.
   Vno - Normal operating speed.

5. 585 nms.

6. 18.5 nms.

7. 88 kts.

8. 2100'.

9. 407 fpm.

10. 224.5 kg/m2.

11. 1298'.

12. Yes.

13. 2260'.

14. 33 USG.

15. After the larger aircraft's touchdown point.

16. 175.6 kts.

17. 90.2''

18. 108.94''

19. Aircraft weight plus full oil and un-useable fuel.

20. Va - Maximum design manoeuvring speed.
    Vne - Never exceed speed.

21. 3 hrs 36 min.

22. You will undershoot.

23. After his touchdown point.

24. Total moments divided by the Total mass.

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25. 92.2".

26. Vx - best angle of climb speed.

27. Rough running engine and a drop in manifold pressure.

28. Normal, Utility and Aerobatic categories.

29. Yes.

30. Enter graph at the reference point of for example intersection of temperature and pressure altitude, move horizontally to the right to the next reference line. Proceed to determine your next vertical parameter, for example your weight. Follow the guidelines down until the 2 lines intersects and from that point move horizontally to the right to the next reference line. Repeat this process until you read off your result on the right hand side of the graph.

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