032 AEROPLANE PERFORMANCE

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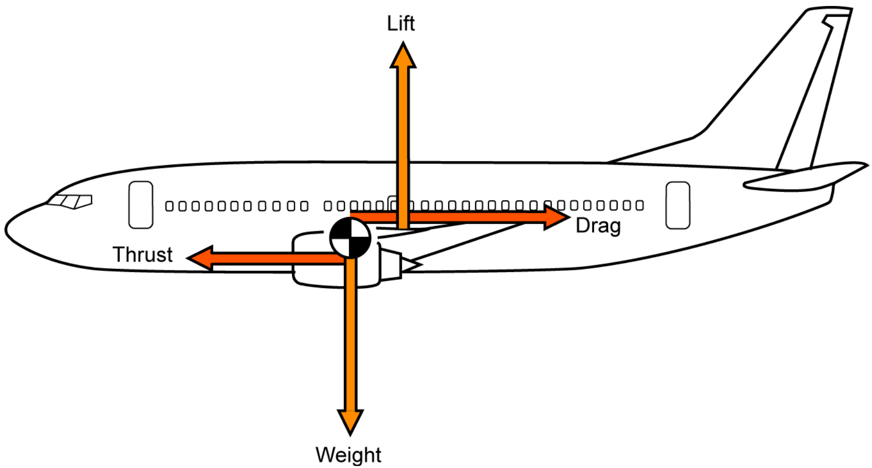
Basic Aerodynamics

Basic Aerodynamics

Level Flight

1. In level, unaccelerated flight there are four main forces acting on an aeroplane. They are lift, weight, thrust and drag. To maintain level flight these forces must remain in equilibrium. Lift must be equal and opposite to weight and thrust must balance drag.

FIGURE 1-1
The Forces in Level Flight



2. To graphically depict the variations in strength of any force against speed then IAS, or more correctly EAS should be used because compressibility must be accounted. However, to show the variation of power, the rate of doing work, against speed then TAS must be used.

Lift

3. Lift may be defined as that force acting on an aeroplane which is at right angles to the direction of the airflow. It can be calculated for level flight at any specified weight and altitude by the formula:

$$\text{Lift} = C_L \tfrac{1}{2} \phi V^2 S.$$

Where C_L = the coefficient of lift; ϕ = air density; V = free air velocity; S = wing area.

4. The coefficient of lift is a mathematical factor that varies with the angle of attack (up to the stalling speed). To maintain level, unaccelerated flight the formula must remain in balance. If the weight and altitude are fixed then the only remaining variables in the formula are the coefficient of lift and the free air velocity. The coefficient of lift is dependent on the angle of attack for its magnitude. Thus if the speed is increased the angle of attack must be reduced to maintain level flight, otherwise the aeroplane will climb. Similarly if the speed is reduced then the angle of attack must be increased or else the aircraft will descend. All angles of attack have a corresponding IAS. **Level flight can only be maintained if the formula remains in balance.**

5. Lift is generated by an aerofoil and is that force which acts upward at right angles to the direction of movement of the aerofoil. It acts through a point on the aerofoil referred to as the centre of pressure (CP). This point moves forward with increasing angle of attack up to the stalling angle where it moves abruptly backward. The normal movement is between 30% and 20% of the chord line from the leading edge. A point, approximately 25% along the chord line from the leading edge, known as the aerodynamic centre is where, no matter what the angle of attack, the pitching movement remains constant at its zero lift value. Lift depends on the following factors:

(a) Forward speed

(b) Air density

(c) Viscosity of the air

(d) Wing shape

(e) Wing area

(f) Angle of attack

(g) Condition of the wing surface

(h) The speed of sound

The value of lift can be calculated from the formula:

$$\text{Lift} = C_L . 1/2 \rho V^2 . S$$

Where C_L , the coefficient of lift is a numerical factor

ρ is the density of the air

V is the forward speed of the aerofoil

S is the wing area which remains constant.

If $1/2\rho V^2$ = indicated airspeed, then lift = $C_L \times IAS \times$ wing area .

6. The coefficient of lift, C_L is affected by the weight, the angle of attack, the wing shape, the Reynolds number and the condition of the wing surface. An increase of weight causes the induced and profile drag to increase resulting in an increased total drag and VIMD, the velocity of minumum drag. The angle of attack affects the value of C_L . With a low angle of attack, the drag is mostly profile and will reduce C_L but with high angles of attack, the drag is mostly induced, resulting in a high C_L . Its value will continue to increase up to the stalling angle at which point it will suddenly reduce.

7. The angle of attack also affects the forward speed or vice versa. If the lift formula is to remain balanced, a low IAS requires a high angle of attack and a high IAS needs a low angle of attack. Should the V in the formula be IAS then, for level flight, the angle of attack will be the same at all altitudes provided the IAS remains constant, because lift and drag will be unchanged. However, if the V is a TAS, then in a normal atmosphere, the TAS will increase up to the tropopause for a given IAS.

8. Climbing at a constant IAS will therefore require the angle of attack to be maintained throughout the climb. However, if the climb is conducted at a constant Mach number, then both the IAS and TAS will reduce in a normal atmosphere and it is then necessary to increase the angle of attack.

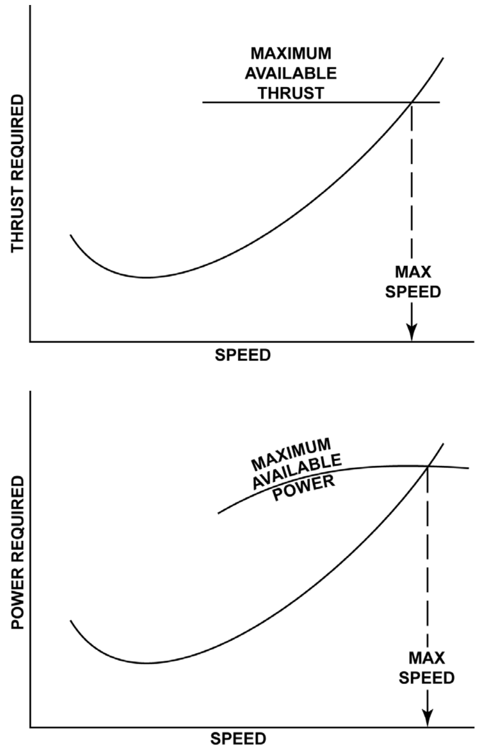
9. For a given angle of attack, the IAS changes in direct proportion to the square root of the weight of the aeroplane.

10. In a descent at constant Mach no., the TAS and IAS increase in a normal atmosphere and in the angle of attack must be decreased progressively with altitude which will increase the descent gradient and pitch angle.

Thrust and Power

11. Thrust is the force produced by the engine(s) of an aeroplane in a forward direction and directly opposes drag. Power is the rate of doing work, it is a measure of the work done by the engine(s), and is the product of thrust x TAS. For any specific weight and altitude graphs may be plotted of the power both attained and required, against speed. Examples of such graphs are shown at Figure 1-2. From these graphs it is possible to ascertain the power required to attain a particular speed or to determine the speed achieved at a particular power setting. The highest speed the aeroplane can achieve where the power available, at the equals the power required. The minimum speed is not usually defined by the power or thrust but by conditions of stability control or stall.

FIGURE 1-2
Level Flight Performance



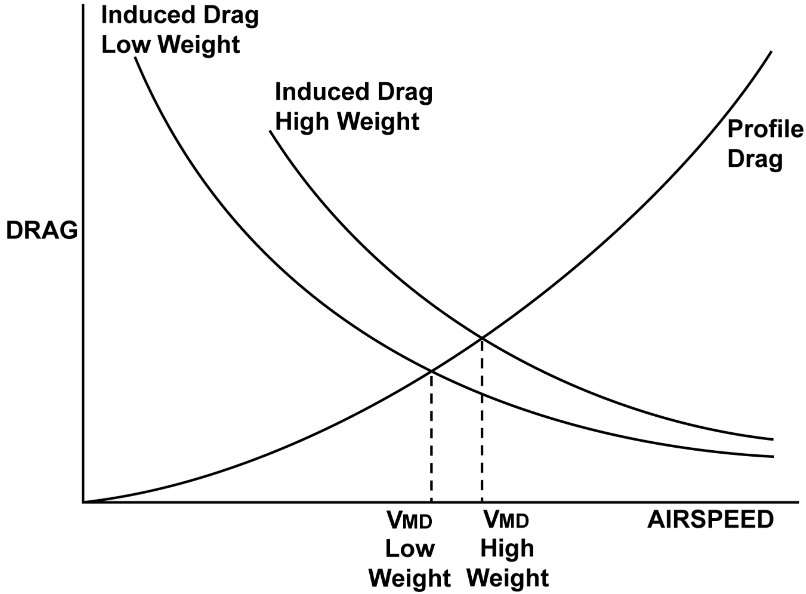
One Power Unit Inoperative. In the event of one power unit becoming inoperative, the power available decreases and the power required increases. Thus the maximum speed is decreased.

Drag

12. The force acting in opposition to thrust and parallel to the airflow, in other words the resistance to forward motion is called drag. It comprises two main components these are induced drag and profile drag.

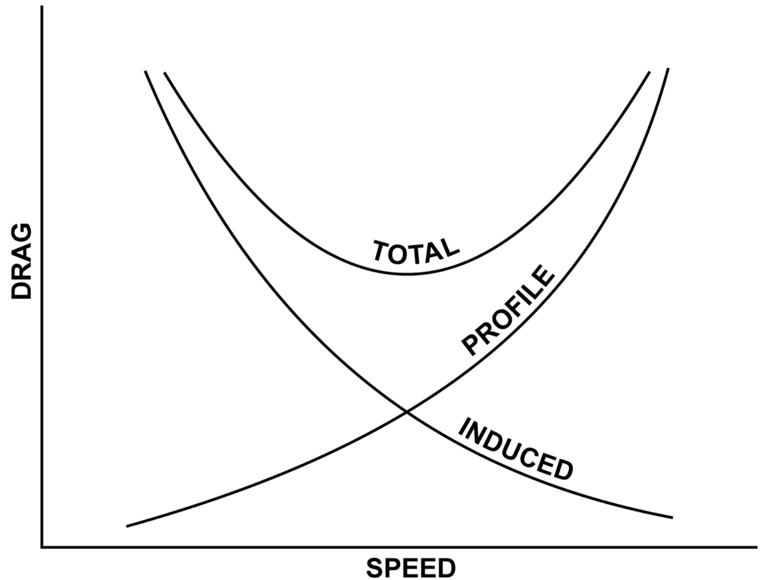
Induced Drag. As an aerofoil moves through the air it creates vortices which oppose forward movement and is referred to as induced drag. The larger the vortices – the greater the induced drag. It is, therefore, dependent on the angle of attack for its magnitude. High angles of attack create large vortices, whereas low angles of attack cause small vortices. Thus induced drag decreases with increase of speed.

FIGURE 1-3
Effect of Weight on Induced Drag



Profile (Parasite) Drag. The resistance caused by the aerofoil shape (form drag), the boundary layer surface friction (skin friction) and the poor of inadequate streamlining (interference drag) is known as profile drag. It is present at all speeds but has an increasingly detrimental effect on aeroplane performance as the speed increases.

FIGURE 1-4
Aircraft Drag

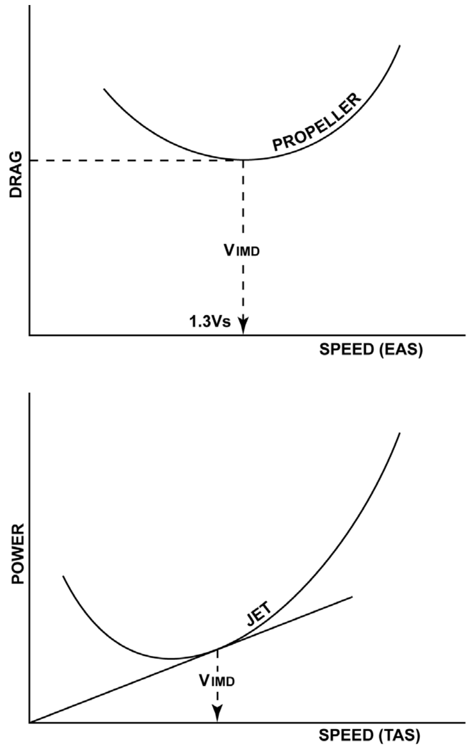


Total Drag. The resultant of all the drag caused by an aeroplane's movement through the air is the total drag. It is slightly more than the sum of the induced drag and the profile drag and as illustrated for propeller driven aeroplanes in Figure 1-4. The profile drag increases in proportion to the square of the speed, e.g. if the speed is doubled then the drag will be quadrupled. This is known as the 'speed squared law'.

The Velocity of Minimum Drag. The lowest point on the total drag curve is the velocity of minimum drag, VIMD. When plotted on a power curve this point is the tangent to the power required curve. See Figure 1-5. The drag versus speed graph shows that the velocity of the minimum drag for the propeller driven aeroplane is approximately 1.3 VS in the clean configuration. From this it can be deduced that propeller driven aeroplanes can be flown at a relatively low speed to maintain steady flight. VIMD reduces with decreased weight and increases with increased weight.

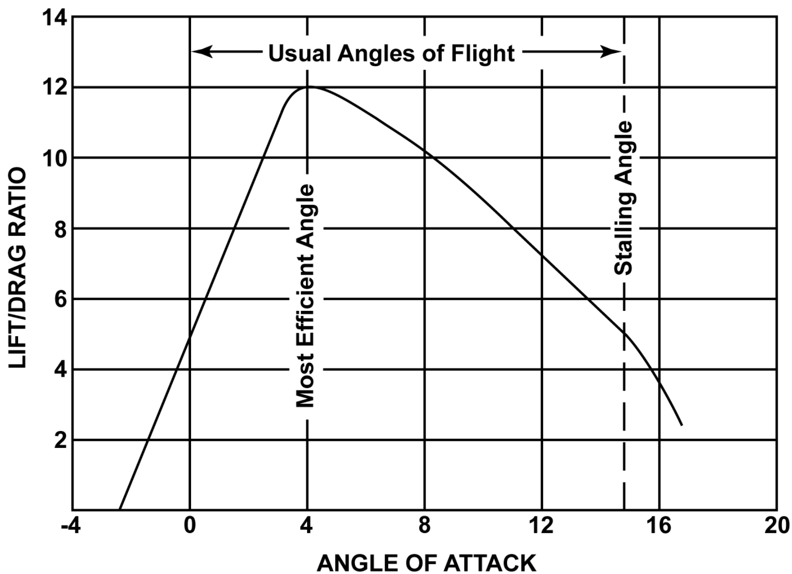
One Engine Inoperative. In the event of one power unit becoming inoperative, the profile drag increases and the induced drag only increases very slightly. This causes the total drag curve to move up and to the left, indicating an increase in total drag and a decrease in the minimum drag curve.

FIGURE 1-5
The Velocity of Minimum Drag



Speed Stability. The tendency of an aeroplane following an undemanded speed disturbance, after the disturbance is removed is referred to as its 'speed stability'. A speed stable aircraft will return to its predisturbed speed whereas one that is unstable will not. Speeds in excess of VIMD are in the normal or 1st regime but speeds below VIMD are referred to as the backside of the drag curve are in the 2nd regime.

FIGURE 1-6
The Lift Drag Ratio



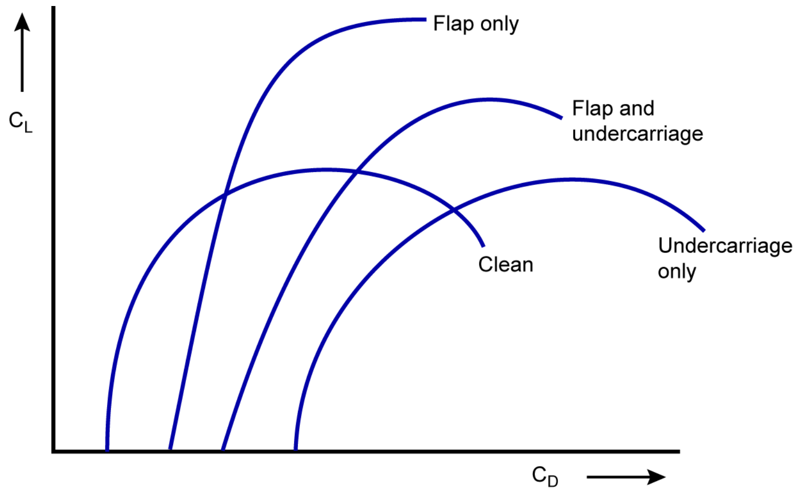
The Lift/Drag Ratio. For any given weight and altitude, level flight can be maintained at any speed between the maximum and the minimum limits by adjusting the angle of attack to keep the lift formula in balance, so that the lift developed is equal to the weight. However, as the angle of attack increases so also does the drag which, to counteract it, will require a greater amount of thrust. Thus the fuel consumption will increase. This is clearly an inefficient way to maintain level flight. The most efficient manner to operate the aeroplane would be to fly at the angle of attack that creates the most lift and causes the least drag. Therefore, the most efficient angle of attack is that which produces the highest lift/drag ratio. This angle of attack is the same for all weights and altitudes.

13. There is only one airspeed, at the most efficient angle of attack, that will keep the lift formula in balance. This, then, is the most economical cruising speed, which as an equivalent airspeed it will be the same at all altitudes but it will increase slightly with increased weight. The lift/drag ratio can be calculated for a range of angles of attack and plotted as in Figure 1-6. In the example the highest lift/drag ratio occurs at 4° and the stalling angle, that is the angle at which the lift developed is insufficient to support the weight is 15°.

C_L versus C_D. The normal relationship of C_L to C_D for a clean aircraft is depicted in Figure 1-7. If flap is lowered the C_D increases and moves to the right and C_L increases by a large amount. The larger the angle of flap set, the greater is this effect. Should the undercarriage now be lowered the C_D will increase and C_L will reduce from the "flap only" position. But if only the undercarriage is selected down with no flap angle set then the additional lift is not available to offset the drag caused by the undercarriage.

FIGURE 1-7

C_L versus C_D.

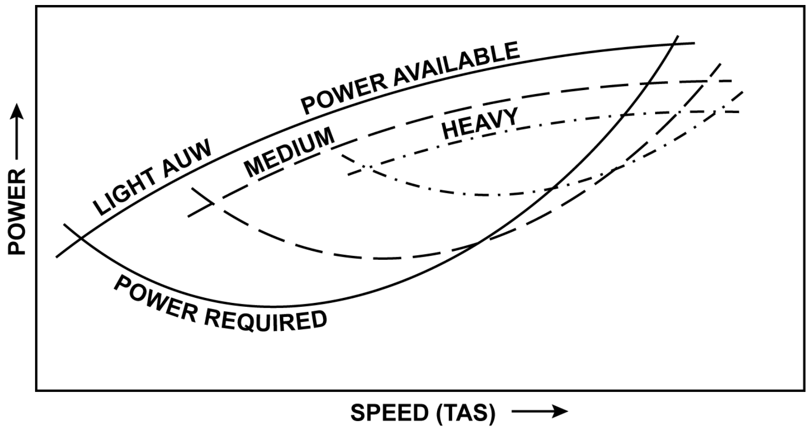


Weight

14. Weight is the force acting on an aeroplane in a vertically downward direction. In level flight it is lift which has to exactly opposes weight. If the weight changes so must the lift alter to match this change, to ensure the lift formula remains in equilibrium. During flight an aeroplane burns fuel which continually reduces its weight and therefore requires a reduction in lift.

15. If the speed remains constant then the excess lift produced over the weight will cause the aeroplane to gradually climb. This is called a cruise climb. However, if level flight is maintained, by reducing the angle of attack, then the aeroplane will gradually increase its forward speed. To maintain level, unaccelerated flight the thrust must be reduced. In other words, as the weight reduces the excess power available increases and the power required decreases. If the weight were to increase the power available would decrease and the power required would increase. The change to the power curves is similar to those resulting form a change of altitude. See Figure 1-8.

FIGURE 1-8
Effect of Weight



Altitude

16. **The Effect of Altitude.** An increase of altitude results in a decreased air density which has the following effects:

(a) **Lift.** At a constant weight, the relationship between EAS and the angle of attack is not affected by a change of altitude. However, less lift will be developed due to the reduced density and if level flight is to be maintained then either the angle of attack must be increased or the speed must be increased. At high cruising TAS the loss of lift is increased by the effects of compressibility and would require further compensation.

(b) **Drag.** By itself the decreased density at increased altitude would cause the drag generated to decrease. If level unaccelerated flight is to be maintained then the increased angle of attack required by a. would cause an increase in drag which would cancel the benefits of the decreased density. The overall effect of increased altitude on drag is, therefore, to make little change.

(c) **Power.** Irrespective of the type of engine, the power attained decreases with an increase of altitude. Because drag is virtually unchanged at all altitudes then the power required to maintain level flight increases with altitude. Therefore, the power available and power required curves become closer together, resulting in a decrease of the maximum speed possible and an increase of the minimum speed. Thus the range of speeds available in level flight decreases with an increase of altitude.

If the curves are plotted against EAS they move up the graph but when plotted against TAS they also move to the right. See Figure 1-9.

FIGURE 1-9
The Effect of Altitude - Propeller Aircraft

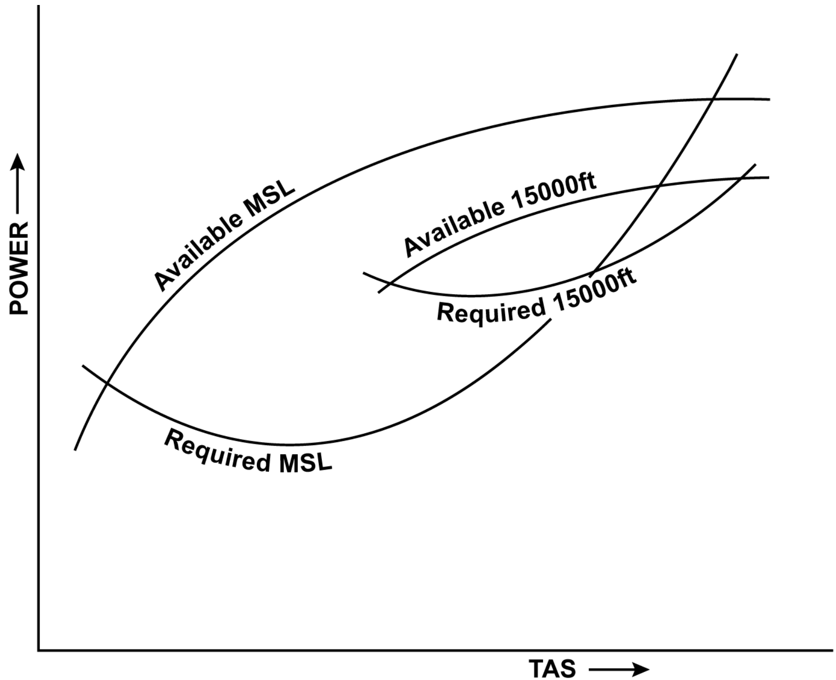
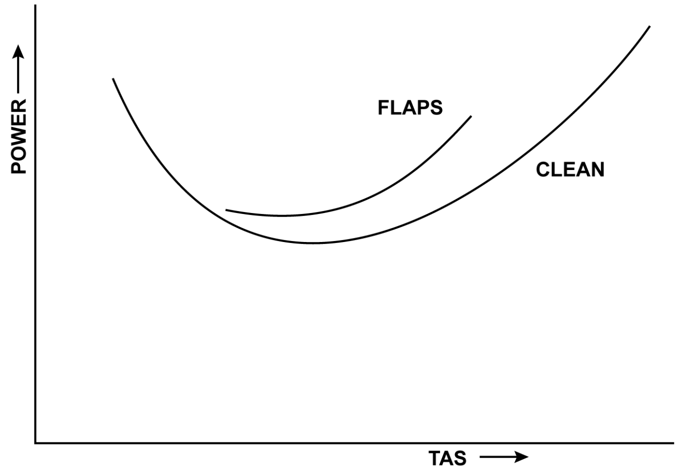


FIGURE 1-10
The Effect of Aircraft Configuration



Aircraft Configuration

17. In flight the aircraft configuration may be changed by lowering the flaps and/or the undercarriage. This will increase drag which will require more power if the aeroplane is to maintain level flight at the same speed. The effect is greater at high airspeeds as shown in Figure 1-10. The actual performance of the aeroplane is determined by the power available. The excess of the power available over the power required is greatly diminished by a change of configuration from the 'clean' state.

Take-off. When the aircraft is lined up ready for take-off the only forces acting on the aeroplane whilst it is stationary are weight and thrust but as the aircraft accelerates the lift and drag increase while the thrust reduces. By the time the aircraft reaches VLOF the thrust equals drag and the lift increases sufficiently to overcome weight. Selecting flap for take-off will increase both the lift and drag and although the take-off distance will be less than the flapless distance, the average drag experienced through the take-off run will be increased.

Climbing Flight

18. Obstacle avoidance is of primary importance to public transport aeroplanes especially just after take-off. Thus the minimum angle of climb is of prime importance during the take-of climb. Of secondary importance during this phase of flight is the rate of climb which governs the time taken to reach a given altitude.

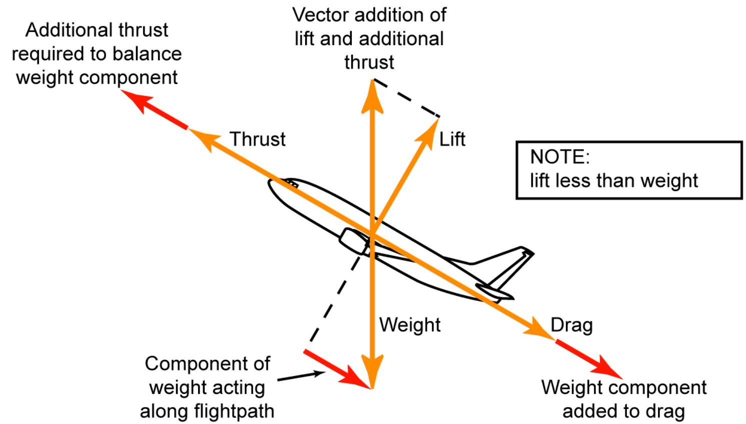
Forces Acting on an Aeroplane in a Climb. The power required to climb at a given EAS is greater than that required to maintain level flight at the same EAS. This is because the thrust has not only to counteract the effects of drag but also that component of weight which acts in the same direction as drag. The lift requirement in a climb is reduced from that of level flight because it only has to counterbalance the component of weight at right angles to the airflow. See Figure 1-11.

Thrust Required = Drag + (Weight x sine angle of climb).

Lift Required = Weight x cosine angle of climb.

The angle of climb is determined by the amount of thrust remaining available after counteracting drag but the rate of climb is decided by the amount of excess power available. Both are reduced if the airspeed increases, an acceleration occurs or a turn is executed during the climb.

FIGURE 1-11
Forces in a Climb



The Maximum Angle of Climb. The angle of climb is determined by the height gain per unit distance. It is, therefore, dependent on groundspeed. A headwind will reduce the ground distance travelled and thus increase the angle of climb. A tailwind will have the reverse effect. To attain the maximum angle of climb the aircraft should be flown at the speed that affords the greatest difference between thrust available and the drag curves when plotted on a 'Drag versus Speed' graph, ie. VX. See Figure 1-12 and Figure 1-13.

By transposition then: Sine angle of climb = (Thrust developed – Drag) ÷ Weight.

19. For propeller driven aeroplanes because thrust varies with speed the best angle of climb is obtained at a speed below the minimum drag speed (V_{IMD}) and below the minimum power speed (V_{IMP}) which is just above unstick speed (V_{US}). See Figure 1-12. This speed is colloquially referred to as V_X usually is approximately 10kts. less than V_Y, the speed for the maximum rate of climb. The value of V_X and V_Y decreases with flap extension. V_X and V_Y increase with weight but are unchanged with altitude or wind component.

20. The normal climb regime for a transport aeroplane is to climb at a constant IAS followed by a climb at a constant Mach number. The altitude at which the speed change takes place is referred to as the ‘crossover altitude’. This altitude is that at which both the IAS and Mach number produce the same TAS. If the constant IAS is altered to a higher value, the crossover occurs at a lower altitude.

21. Climbing at a constant IAS will cause the TAS and Mach number to increase. Although a constant angle of attack is maintained, the climb gradient and rate of climb will both decrease because of the decreasing excess of power available over power required. After changing to a constant Mach number, both the IAS and TAS will gradually decrease. Because of this the angle of attack must be increased. Consequently, despite the decreasing power available the climb gradient increases. Therefore, in a normal atmosphere, at the crossover altitude the climb gradient changes from one that is decreasing to one that is increasing.

FIGURE 1-12
The Maximum Angle of Climb. Propeller Aircraft.

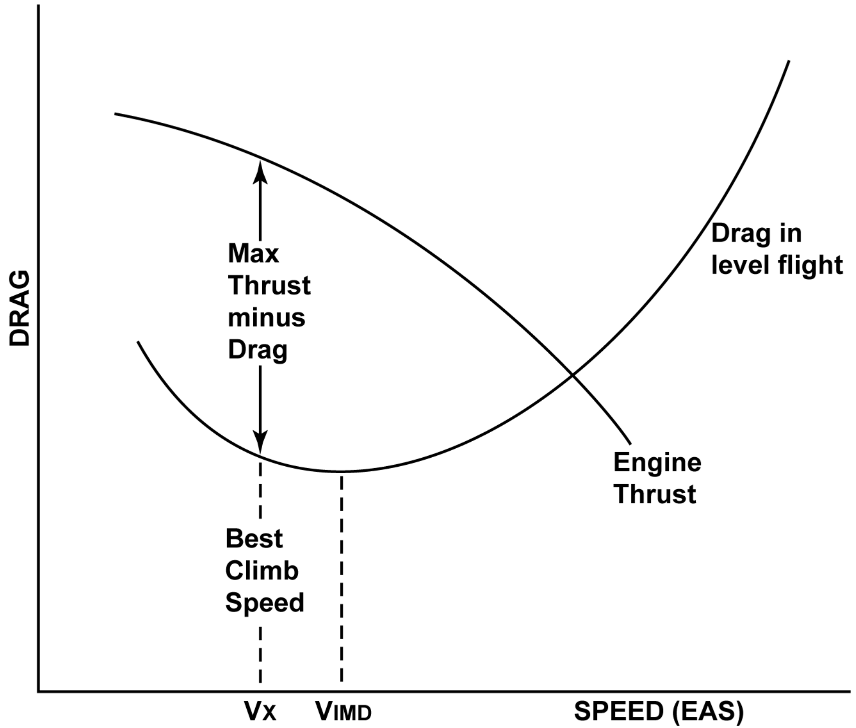
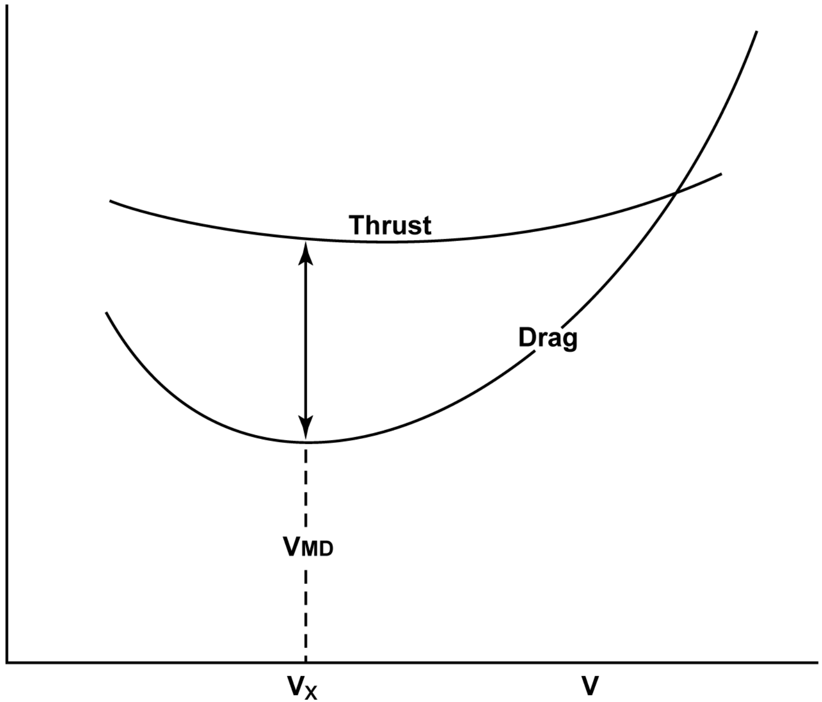


FIGURE 1-13

Maximum Angle of Climb. Jet Aircraft.



The Calculation of Climb Gradient. The gradient of climb is determined by the excess of thrust over drag and can be determined from the forces acting in that climb (see Figure 1-10) by the formula:

$$\text{Climb Gradient} = \text{Total drag} = \frac{\text{Lift}}{\text{L/D ratio}}\ \text{kgs}$$

Up to 15° climb angle it is safe to assume that lift equals weight and that the climb gradient equals the sine of the angle of climb. Total thrust equals (number of engines x Newtons per engine ÷ g m/s/s/) kgs.

$$\text{Total drag} = \frac{\text{Lift}}{\text{L/D ratio}}\ \text{kgs}$$

EXAMPLE 1-1

EXAMPLE

Given a four jet aircraft weight 150,000kgs, climbing with L/D ratio 1:15. Each engine has a thrust of 75,000 Newtons and g = 10 m/s/s/. Calculate gradient of climb .

SOLUTION

$$\text{Total thrust} = \frac{4 \times 75000}{10} = 30,000\text{kgs}$$

$$\text{Total drag} = \frac{150,000}{15} = 10,000\text{kgs}$$

$$\text{Gradient} = \frac{30,000 - 10,000}{150,000} \times 100 = 13.3\%$$

Calculation of Rate of Climb. The rate of climb may be determined by formula or by rule of thumb. The formula is derived from the gradient formula:

$$\text{Gradient} = \frac{\text{ROC fpm}}{\text{TAS kts}} \text{ in still air, or}$$

$$\text{Gradient} = \frac{\text{ROC fpm}}{\text{groundspeed kts}} \text{ accounting wind}$$

Therefore, ROC = gradient x groundspeed kts.

EXAMPLE 1-2

EXAMPLE

Given gradient of climb 5%, groundspeed 250 kts. Calculate rate of climb (approx).

SOLUTION

ROC = 5 x 250 = 1250 fpm.

EXAMPLE 1-3

EXAMPLE

Given: An aircraft at a weight of 110,000kgs. Attains a climb gradient of 2.8%. At what maximum weight will it attain 2.6%?

SOLUTION

$$\frac{2.8}{2.6} \text{ x } 110{,}000 = 118{,}460\text{kgs}$$

EXAMPLE 1-4

EXAMPLE

Given: A three-engined aeroplane develops 50,000 Newtons of thrust per engine and has a total drag of 72,569 Newtons. If $g = 10 m/s^2$ with one engine inoperative what is the maximum weight at which it can attain a gradient of climb of 2.7%?

SOLUTION

$$\text{Gradient} = \frac{(\text{Thrust} - \text{Drag})\ \text{kgs}}{\text{Weight kgs}} \text{ x } 100$$

$$\text{Weight kgs} = \frac{(\text{Thrust} - \text{Drag})\ \text{kgs}}{\text{Gradient}} \text{ x } 100$$

$$\text{Weight kgs} = \frac{(100,000 - 72569)\ \text{kgs}}{2.7 \times 10} \text{ x } 100$$

$$= 101{,}596 \text{ kgs}$$

EXAMPLE 1-5

EXAMPLE

Given: A four engined aeroplane weighting 150,000kgs. Has a lift/drag ratio of 1 : 14 and develops 75,000 Newtons of thrust per engine. g = 10 m/s^2. Calculate the maximum gradient of climb.

SOLUTION

$$\text{Total thrust} = \frac{4 \times 75,000}{10} = 30,000\text{kgs}$$

$$\text{Total drag} = \frac{150,000}{14} = 10,714.28 \text{ kgs}$$

Note: At low angled climbs lift is assumed to equal weight.

Thrust - Drag = 30,000 - 10,714.28 = 19,285.72 kgs

$$\text{Gradient} = \frac{19,285.72}{150,000} \times 100 = 12.86\%$$

The Maximum Rate of Climb. The rate of climb is defined as the height gain per unit of time. The maximum rate of climb is determined by the amount of excess power available above that which is required for the climb and can be calculated by the formula:

Rate of Climb = Excess power available ÷ Weight

Because the formula is dependent on the power available, any factor that reduces the power available, reduces the rate of climb. The following have this effect:-

(a) Decreased power setting

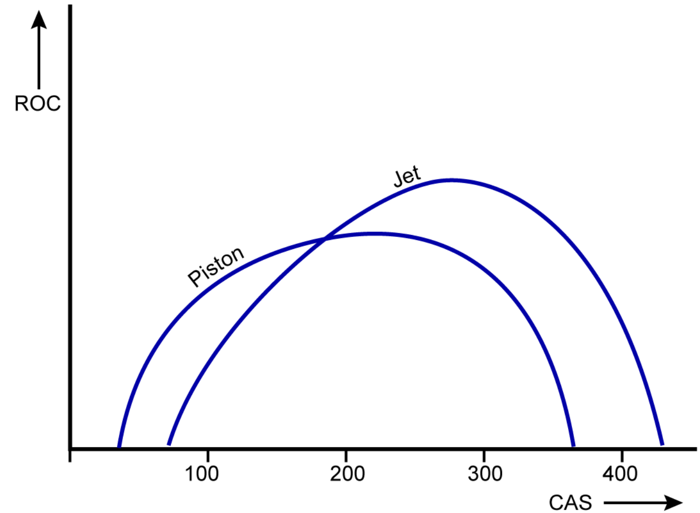
(b) Increased weight

(c) Increased flap angle

Speed has a variable affect on the rate as shown in Figure 1-14.

If flap is extended the graph curves move down and to the left. Although the along track wind component affects the gradient of climb, increasing it is a headwind and decreasing it in a tailwind because the distance travelled is directly affected, it has no affect on the rate of climb. A more detailed explanation is on Page 8-3.

FIGURE 1-14
ROC versus CAS



Propeller Driven Aeroplanes. The climbing speed that gives the best rate of climb for a propeller driven aircraft is the velocity of minimum power because at this point the difference between the power available and the power required curves is at its maximum. This usually occurs at the velocity of minimum power, VIMP, but may be slightly higher than this dependant on the power available curve. It is often referred to as VY. See Figure 1-15 and Figure 1-16.

FIGURE 1-15
Maximum Rate of Climb - Propeller Aircraft MSL for a Piston Engine

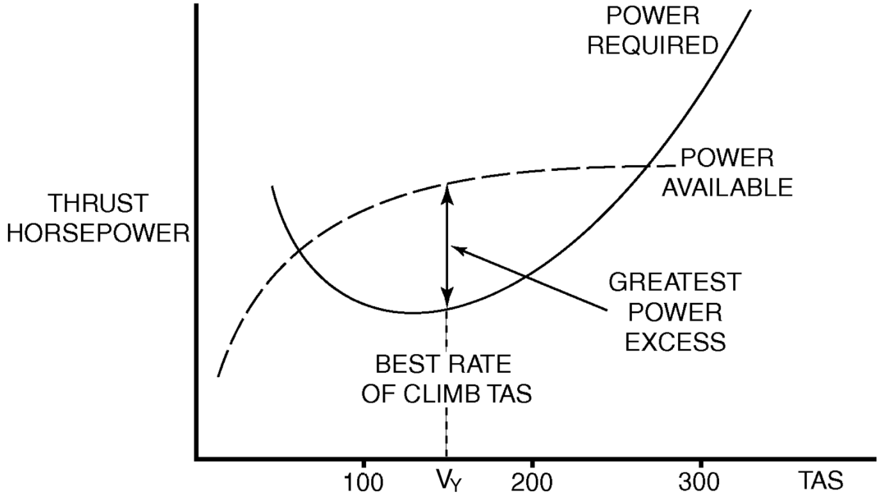
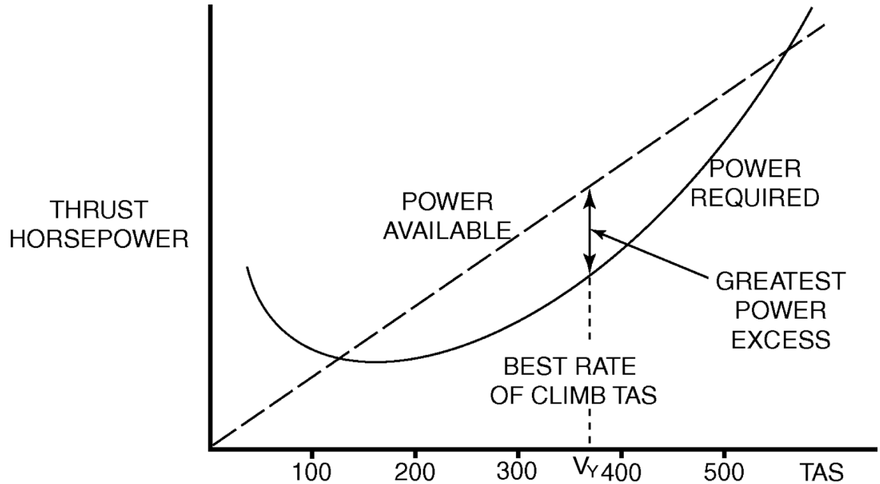


FIGURE 1-16
Maximum Rate of Climb - Propeller Aircraft MSL for a Jet Engine



The Effect of Altitude on Climb Performance

22. The power attained by both propeller and jet driven aeroplanes decreases with altitude. The power available curves are therefore lowered whilst the power required curves are displaced upwards and to the right. Thus the power required to fly at VIMD is increased and the rate of climb reduces. The range of speeds available between minimum and maximum is also reduced. See Figure 1-17.

Aircraft Ceiling. At the point at which the power available curve only just touches the power required curve a climb is no longer possible. Furthermore there is only one speed possible in level flight. This is the absolute ceiling, which is of little practical use because it is a long slow process to reach it. See Figure 1-18 and Figure 1-19.

For practical purposes an artificial ceiling called the 'service ceiling' is introduced which is defined as that altitude at which the maximum rate of climb is 500 fpm (2.5m/s) for jet aircraft and 100fpm (0.5m/s) for propeller driven aeroplanes.

FIGURE 1-17
The Effect of Altitude. Example Approximately 10,000 ft

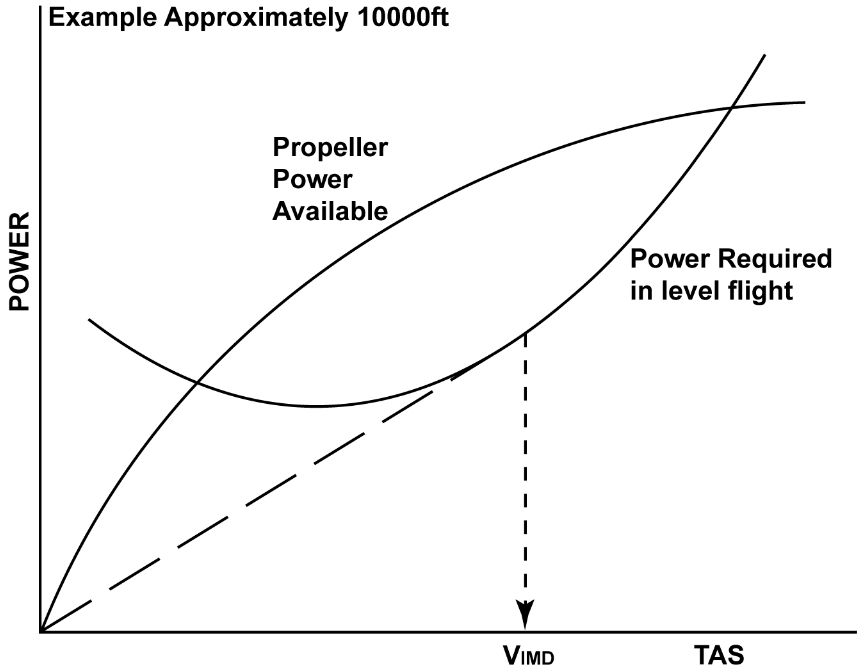


FIGURE 1-18
Example Approximately 20,000 ft

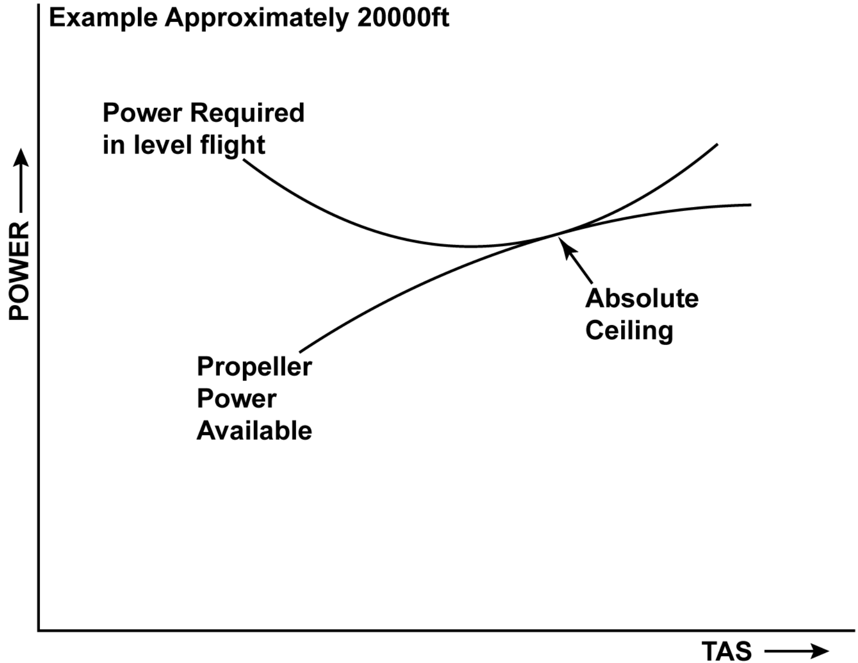
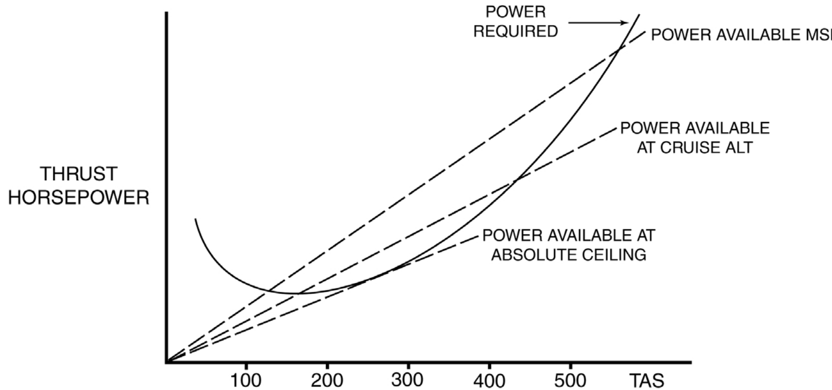


FIGURE 1-19
Effect of Altitude on Power Available (Jet)



The Buffet Onset Boundary Chart

23. An aeroplane at high altitude in the cruise configuration is in a condition that the forces acting on the aeroplane are in a state of equilibrium. Because of the high TAS at this altitude any disturbing force will cause a large deviation from the original state. The dynamic stability of the aeroplane at such altitudes is reduced and the damping of such deviations is diminished. The aeroplane is less stable and any control movements to recover to the original altitude and/or altitude must be made slowly and smoothly.

24. Buffet is vibration to the airframe which, if excessive and prolonged, could cause structural damage to the aeroplane, interfere with the control of the aeroplane and may result in excessive crew fatigue. Whilst cruising, buffet may be experienced for one of two reasons. At low speed it will be felt just prior to the aeroplane stalling, known as the pre-stall buffet, which occurs at approximately 1.2 VS. When approaching the maximum speed limit the high-speed buffet will be experienced. Except for stall warning buffet, there should be no perceptible buffet at any speed up to VMo/MMo (JAR 25.251(d)).

25. The speed range available at which to cruise is, therefore, between 1.2 VS and VMo/MMo. Pilots are well aware of the consequences of stalling the aeroplane and are very cautious when the speed approaches this value. Although a warning device is fitted to the aeroplane which activates at this low speed, it is unlikely that the pilot would allow the speed of the aeroplane to fall to this speed inadvertently. However, it is possible to inadvertently exceed the VMo/MMo and encounter the high-speed buffet. This increase in speed may be caused by gust upsets, unintentional control movement, passenger movement, levelling off from a climb or a descent from Mach to airspeed limit altitudes. For such an eventuality a high-speed aural warning device is fitted to most aeroplanes and additionally a maximum speed needle on the airspeed indicator shows VMo up to the altitude at which VMo=M_{Mo} where the datum becomes M_{Mo}. The aural warning will sound at approximately 10kts above VMo or 0.01 above M_{Mo}.

26. For normal operations it is possible to construct a graph against altitude to produce an envelope within which it is safe to operate in the cruise which is limited by the buffet onset. The lower limit being defined by the pre-stall buffet and the upper limit by VMo/$M_{Mo.}$ This should produce a sufficient range of speeds and load factors for normal operations. Inadvertent excursions beyond the boundaries of the buffet envelope may not result in unsafe conditions without prior adequate warning to the pilot (JAR25.251(c)).

27. Although the maximum limit of the buffet boundary is fixed for all weights, the lower limit increases with increased weight. Therefore the range of speeds available for normal operations increases as the weight decreases with fuel burn. For any given weight, centre of gravity position and airspeed the maximum operating altitude is that at which it is possible to achieve a positive normal acceleration increment of 0.3g without exceeding the buffet onset boundary (ACJ 25.1585(c)). It is therefore common practice to draw the 'buffet onset boundary' chart for 1.3g. The intersection of the pre-stall buffet and VMo/M_{Mo} lines defines the 'manoeuvre ceiling' (JAR 25.251(e)2). It follows then that as altitude increases manoeuvrability becomes increasingly restricted and the margins to both the high and low speed buffets are reduced. In good weather this is of little consequence, however, in bad weather it has great significance because of the possibility of turbulence disturbing the 'status quo' and requiring correction which becomes increasingly more difficult as altitude increases. As shown at Figure 1-20 and Figure 1-21.

FIGURE 1-20

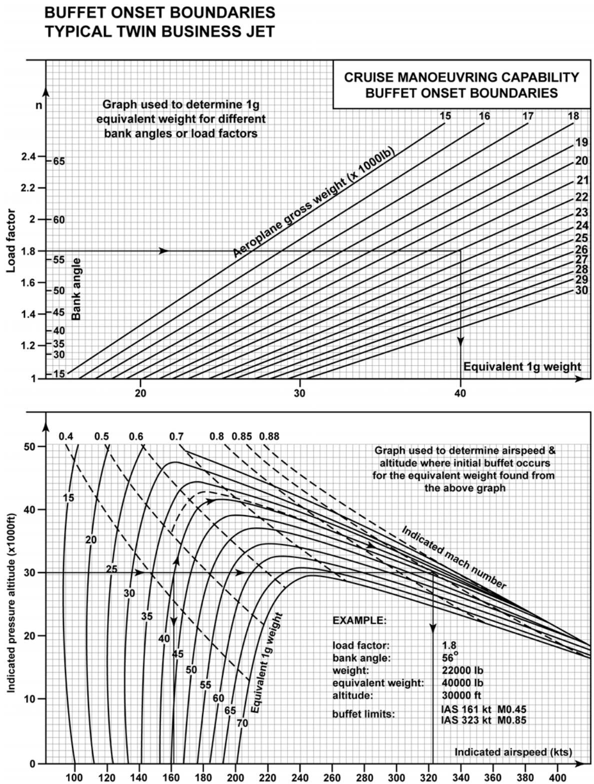
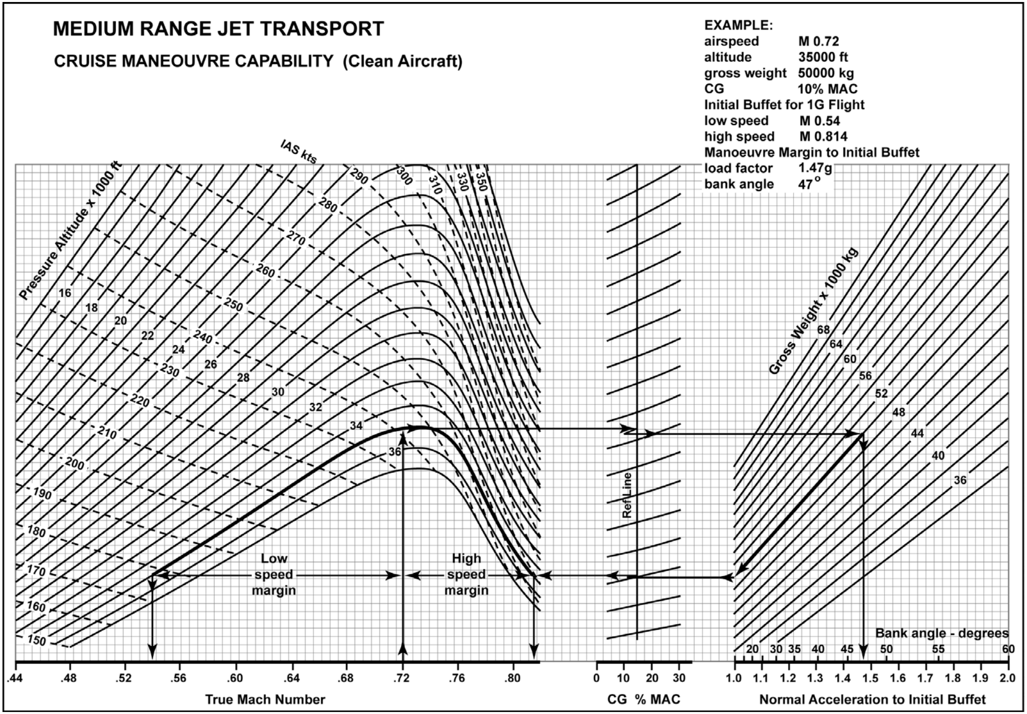

BUFFET ONSET BOUNDARIES
TYPICAL TWIN BUSINESS JET
CRUISE MANOEUVRING CAPABILITY
BUFFET ONSET BOUNDARIES
Graph used to determine 1g equivalent weight for different bank angles or load factors
Load factor
n
Bank angle
Aeroplane gross weight (x 1000lb)
Equivalent 1g weight
15 16 17 18 19 20 21 22 23 24 25 26 27 28 29 30
20 30 40
Graph used to determine airspeed & altitude where initial buffet occurs for the equivalent weight found from the above graph
0.4 0.5 0.6 0.7 0.8 0.85 0.88
Indicated mach number
Indicated pressure altitude (x1000ft)
Equivalent 1g weight
Indicated airspeed (kts)
EXAMPLE:
load factor: 1.8
bank angle: 56°
weight: 22000 lb
equivalent weight: 40000 lb
altitude: 30000 ft
buffet limits: IAS 161 kt M0.45
IAS 323 kt M0.85

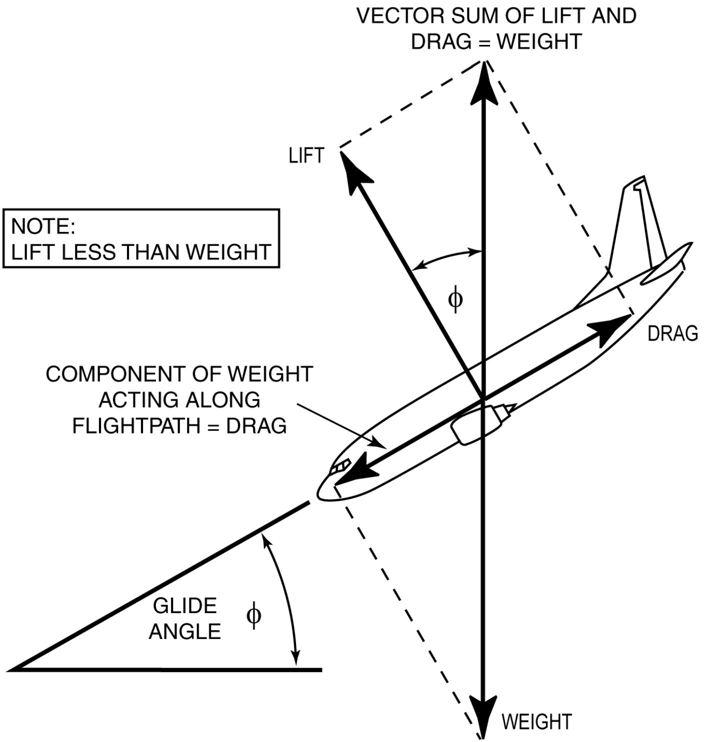
FIGURE 1-21


MEDIUM RANGE JET TRANSPORT
CRUISE MANOEUVRE CAPABILITY (Clean Aircraft)
EXAMPLE:
airspeed M 0.72
altitude 35000 ft
gross weight 50000 kg
CG 10% MAC
Initial Buffet for 1G Flight
low speed M 0.54
high speed M 0.814
Manoeuvre Margin to Initial Buffet
load factor 1.47g
bank angle 47°
IAS kts
Pressure Altitude x 1000 ft
Low speed margin
High speed margin
Ref Line
Gross Weight x 1000 kg
Bank angle - degrees
True Mach Number
CG % MAC
Normal Acceleration to Initial Buffet

Descending Flight

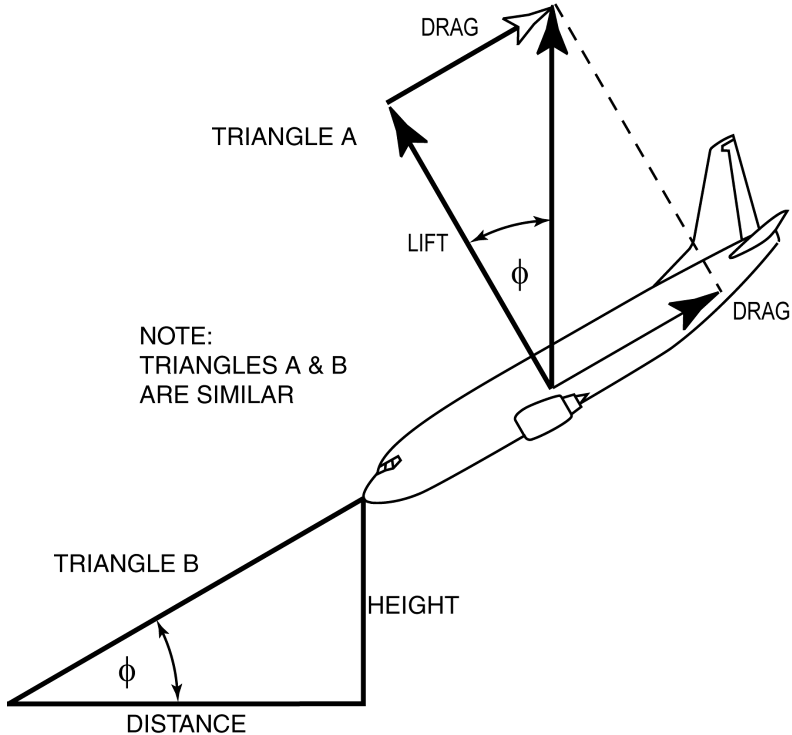
28. A descent may be made with power on or off. If the power remains on, it will be at a recommended setting to achieve a specified goal. If the power setting made is to the idle condition, then it is considered to be a glide descent during which the engines do not contribute to the forward thrust. The forces acting on an aeroplane in a glide descent are depicted in Figure 1-22. Lift, drag and weight act in the usual manner, however thrust is replaced by the component of weight acting along the descent path, which is equal to the weight multiplied by the sine of the angle of descent i.e. $W \sin\phi$

FIGURE 1-22
Forces in a Glide



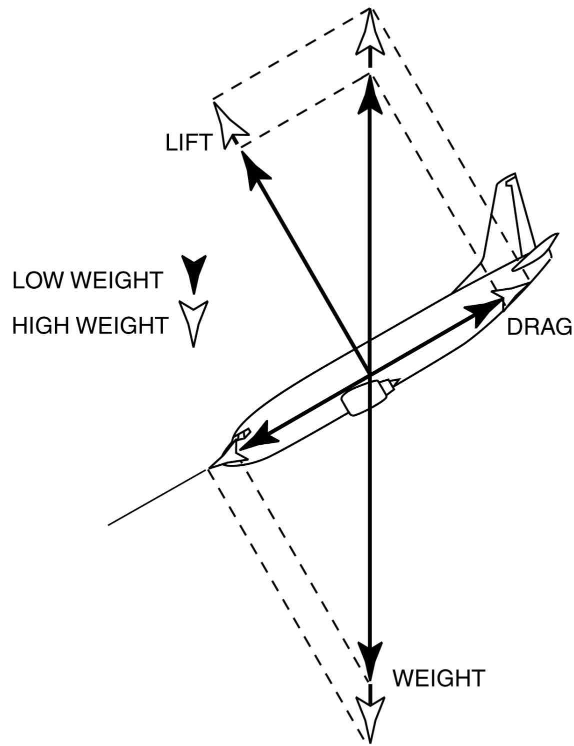
29. For a descent at a constant angle, the lift/drag ratio will remain constant. In Figure 1-23 the lift/drag ratio is represented in triangle ABC as $\frac{AB}{BC}$. It can be seen that triangle EFG is similar to triangle ABC, therefore the lift/drag ratio can be represented by the $\frac{\text{distance travelled}}{\text{height}}$. Provided the glide angle remains constant then the lift/drag ratio will remain constant.

FIGURE 1-23
L/D Ration v Height/Distance in a Glide



30. Figure 1-24 illustrates the effect of weight. An increased weight will increase the forward speed of the aeroplane as well as the lift and drag. The lift/drag ratio remains the same and is unaffected by weight. Hence the glide angle is unchanged. The only effect is that the aeroplane will descent at a higher speed. As the speed is increased, so also is the rate of descent.

FIGURE 1-24
Effect of Weight on L/D Ratio



31. Descending at a constant Mach number in a standard atmosphere will cause the TAS and IAS to increase. Consequently, the angle of attack must be progressively decreased which will gradually increase the gradient of descent and pitch angle. This will increase the margin from the low speed buffet and decrease the margin to the high speed buffet. To maintain a constant descent gradient, the angle of attack (C_L) must be increased and pitch angle decreased.

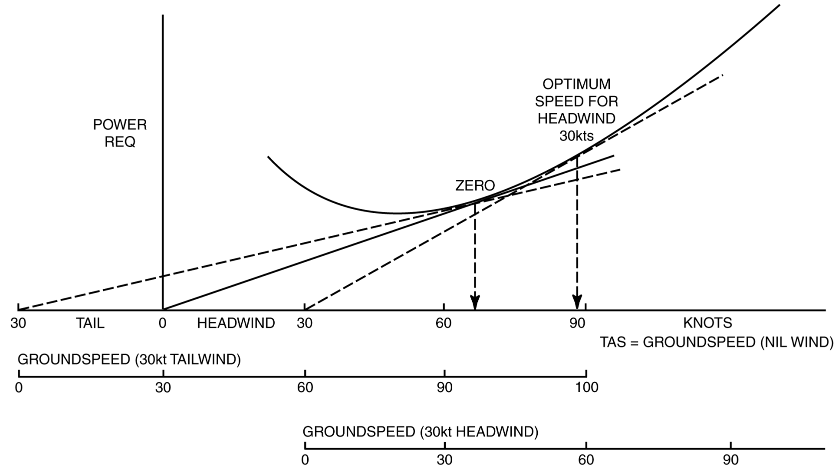
32. If a descent is made at a constant IAS in a standard atmosphere, the gradient of descent and pitch angle will remain constant. Should a particular gradient of descent be required, then the pitch angle must be adjusted during the descent.

33. The distance travelled during the descent is maximised by using the pitch angle that produces the optimum angle of attack. This angle of attack is determined by the airspeed, decreasing the pitch angle below the optimum will increase the airspeed and vice versa. Any angle of attack, other than the optimum, will decrease the glide distance. An increase of pitch angle will decrease the angle of attack, the co-efficient of lift and the lift/drag ratio.

34. The use of flap to descend will increase the lift generated. To maintain the same glide path, the pitch angle would have to be adjusted and the forward speed decreased.

35. To obtain the optimum distance in a descent it is necessary to increase the speed in a headwind which increases the power required. The reverse is true for a tailwind. Despite increasing the speed in a headwind, the distance travelled over the ground will be less than it would have been at the same speed in still air. Hence the descent gradient is increased. Because of the increased speed in a headwind, the overall effect compared with the speed used in still air is that the distance travelled and the descent gradient are very similar to the still air equivalents. See Figure 1-25.

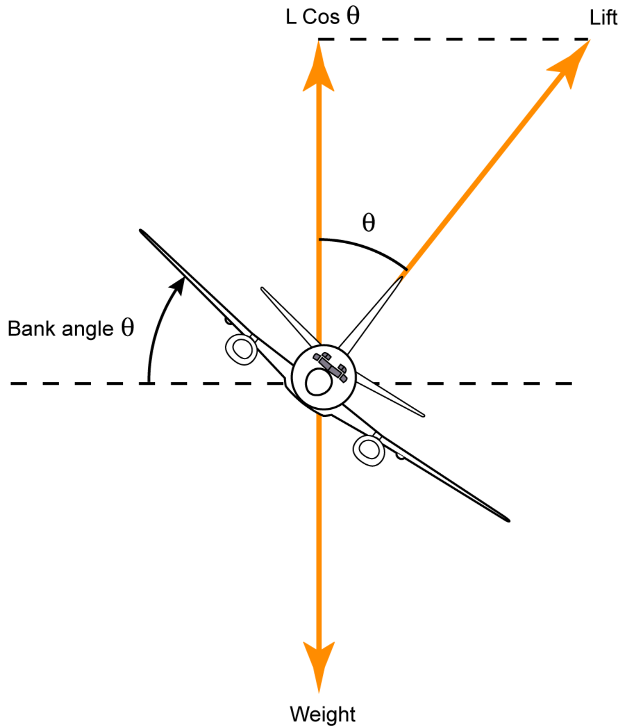
FIGURE 1-25
Effect of Wind on Glide



Turning Flight. The balance of forces acting on an aeroplane in flight changes during a turn because lift no longer directly opposes weight. See Figure 1-26.

FIGURE 1-26

Forces in a Turn



The lift during a turn must be increased because the weight equals L cos θ.

$$\text{The load factor (n)} = \frac{\text{Lift}}{\text{Weight}}$$

$$\text{Therefore in a turn the load factor} = \frac{\text{Lift}}{\text{Lift}\cos\theta} = \frac{1}{\cos\theta}$$

For a 30° banked turn the load factor = 1.1547

For a 60° banked turn the load factor = 2

Thus the load factor increases with increased angle of bank.

Engine Performance

Maximum Range and Endurance

Engine Performance

Definitions

1. The gross or total thrust is the product of the mass of air passing through the engine and the jet velocity at the propelling nozzle.

2. Momentum drag is the drag due to the momentum of air passing through the engine relative to the aircraft's velocity.

3. Net thrust is the resultant force acting on the aeroplane in flight which is equal to the gross thrust minus the momentum drag.

Thrust Rating

4. The thrust forces in an engine are the gas loads which result from the pressure and momentum changes of the gas stream reacting on the engine structure and its rotating components. Some are forward and some are rearward forces. The excess of the forward forces over the rearward force is known as the rated thrust of an engine.

5. Engine thrust is displayed on a gauge as engine pressure ratio (EPR). The pilot selects the appropriate EPR by adjusting the thrust levers. The fuel flow is then automatically adjusted by the control system to maintain the set thrust accounting any variance of altitude, airspeed and inlet-air temperature. Thus the thrust remains at a constant value; this is referred to as a flat rated system. The flat rating cut off is the limit of the compensation available and is shown by a line across the EPR graph in the AFM. If the thrust levers are set to obtain an EPR value above the cut-off line, the automatic system cannot compensate by reducing the fuel flow. In which case the engine temperature may exceed the safe maximum limit and could cause serious damage to the engine.

6. The thrust ratings that are certified are:

(a) Maximum take-off thrust

(b) Maximum continuous thrust

(c) Maximum go-round thrust.

Maximum cruise thrust is not a certificated rating.

Air Density

7. The density of the atmosphere is affected by three factors; altitude, temperature and water vapour content. An increase in any one factor, or any combination of these factors will result in reduced air density. The water vapour content is varied only by a change of air mass, of the other two factors, altitude has by far the greater affect on the density. Thus an increased altitude in a normal atmosphere is only partially compensated by the decreased temperature. This compensation ceases at the tropopause because the temperature remains constant above this altitude.

8. Because air density affects the mass flow of air through the engine, it directly influences the thrust output. Therefore, thrust gradually decreases with increased altitude up to the tropopause above which the decrease in thrust is at a greater rate. Hence, in terms of thrust, it is more beneficial to fly below the tropopause than above it.

9. At low temperatures, the mass flow is greater than it would be at a relatively higher temperature at the same altitude. To maintain the same compressor speed, the fuel flow must be increased or else the engine speed will fall. Thus the thrust is increased for a given RPM.

10. For take-off in a low density atmosphere the thrust will fall for a given RPM. Therefore it is necessary to inject water or water methanol into the engine to restore the lost thrust for take-off.

Engine RPM

11. Mass flow is directly affected by engine RPM. High RPM increases mass flow which consequently increases fuel flow and thrust. Most jet aeroplanes cruise at 85% to 90% of their maximum RPM. During the approach to land, it is important to keep the RPM high in case it is necessary to go-around. This will minimise the time taken to reach the go-around EPR or 'spool up' after initiation.

Airspeed

12. In the cruise at approximately 300kts TAS the forward speed of the aeroplane increases the intake air pressure which is called the 'ram effect'. This increases the density and therefore the gross thrust, which is depicted by the reduced velocity differential between the intake and exhaust gases. Overall at constant RPM there is a gradual rise of gross thrust as speed increases. Thus fuel flow increases at subsonic speeds which results in a decrease of net thrust as speed increases. Therefore, the specific fuel consumption (SFC) increases with speed for a turbo-jet aeroplane.

Weight

13. A high weight requires a large amount of lift to be generated at the wings. This in turn requires a higher airspeed which is obtained by an increase of thrust and hence RPM. Therefore the fuel flow increases because of the increased RPM. Fuel flow is directly proportional to weight.

Fuel Flow

14. The amount of fuel consumed per hour is referred to as the fuel flow. Its value is affected by many factors. Increased air density, ambient temperature, engine RPM, airspeed and weight all increase the fuel flow. However, the fuel flow can be decreased by maintaining the CG just forward of the aft limit. This reduces trim drag and is referred to as 'flying the flat aeroplane'.

SFC and SAR. The specific fuel consumption (SFC) of an aeroplane is the amount of fuel used per unit of thrust. Thus SFC = Fuel consumption ÷ Thrust. The specific air range (SAR) is the distance flown per unit of fuel which is equal to the TAS ÷ fuel consumption. In the cruise for a jet aircraft, thrust equals drag so the formula becomes $SAR = \frac{TAS}{FC} = \frac{TAS}{SFC \times drag} = \frac{1}{SFC} \times \frac{TAS}{drag}$

In the cruise, if one engine becomes inoperative, the TAS will reduce and the drag will increase thus the SAR will decrease.

Maximum Range and Endurance

Maximum Range

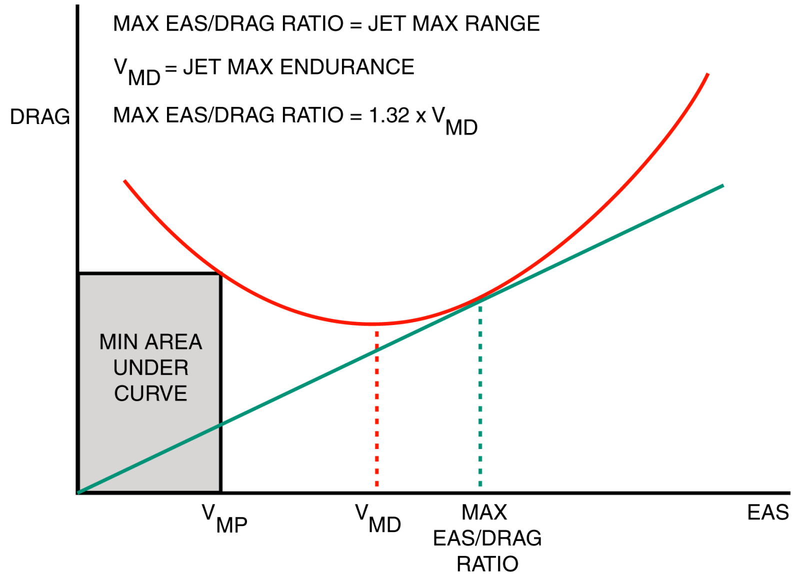
15. Flying for range means travelling the greatest possible ground distance, using the fuel available. To achieve maximum range using a given quantity of fuel, an aeroplane must consume the lowest possible amount of fuel for each nautical mile travelled over the ground. In other words it must attain the lowest possible gross fuel flow. Gross fuel flow (GFF) = fuel flow ÷ groundspeed. The optimum altitude is that at which the maximum specific air range (SAR) is attained.

Piston/Propeller Power Units. As speed increases the thrust developed by a piston/propeller unit combination decreases. Therefore power unit efficiency is greater at low IAS. Maximum airframe efficiency is attained at the speed at which the lift/drag ratio is the highest. Thus VIMD will accommodate both the airframe and power unit requirements. For comfort and controllability, however, the aeroplane should be flown at a speed just above VIMD. The manufacturers usually recommend 1.1 VIMD. The highest measure of aeroplane efficiency can be attained at only one particular altitude, any deviation from this altitude results in a loss of efficiency.

Jet Power Units. At a set RPM, the thrust developed by a jet engine is almost constant for all speeds. Fuel consumption is directly proportional to thrust and, therefore, to RPM but is unaffected by speed. Thus greater engine efficiency is obtained at high IAS.

16. If this was the only consideration the maximum range would be obtained at an IAS much higher VIMD. However, speed affects the angle of attack, which in turn affects the Lift/Drag ratio. The ideal aerodynamic cruise speed for a jet aircraft is at the IAS obtained at the tangent to the drag curve. See Figure 2-1. This is the maximum IAS for the least amount of drag, VI/DMAX. Thus, the most efficient manner in which to operate a jet aircraft is at the angle of attack and IAS which together produce the best VI/DMAX ratio.

FIGURE 2-1
Jet Range and Endurance



17. Because maximum range requires the lowest possible gross fuel flow then the aeroplane should be flown at the altitude at which the IAS produces the highest TAS. At 40,000 ft the TAS produced for a given IAS is almost double that produced at MSL. An additional benefit of high altitude flight is that, for a given RPM the fuel flow reduces because of the decreased air density. The GFF is, therefore, reduced by both the increased TAS and the decreased fuel flow. The maximum range for a jet aircraft is, therefore, increased with altitude.

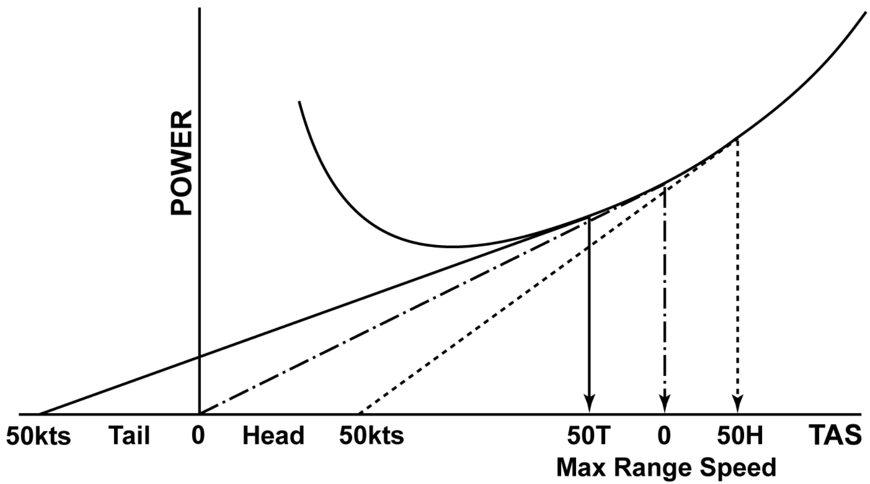
Weight Effect. Irrespective of the type of power unit, if weight is increased then the speed must be increased to develop more lift as a counterbalance. But this increases the drag to a greater extent and causes the lift/drag ratio and the operational efficiency to decrease. Thus, increased weight decreases the maximum range.

Power Setting. If the power setting is changed from that which will produce the maximum range it will adversely affect the range. Increasing power increases the fuel flow proportionally greater than the speed increase hence the GFF increases. Decreasing the power decreases the fuel flow but disproportionately decreases the speed. Therefore the GFF will increase. Any power change will decrease the range.

Wind Effect. Maximum range is dependent on the gross fuel flow, which is a measure of operational efficiency. To increase the range GFF must be reduced. Thus to improve range it is necessary to increase the groundspeed or to reduce the fuel flow or both. The factors affecting fuel flow have already been described and showed that for maximum aeroplane efficiency there is only one altitude at which to fly. However, this altitude is not necessarily the most efficient operational altitude by reason of the ambient temperature and/or along track wind component.

18. To obtain the highest possible groundspeed the altitude may have to be reduced to take advantage of the prevailing wind and/or temperature at a lower altitude. More often than not a compromise altitude will have to be flown because the effect that temperature and altitude have on fuel flow and TAS must be considered, as well as the along track wind component effect on groundspeed, at each altitude. To obtain the maximum range the most beneficial balance has to be calculated. If the problem is one of radius of action, instead of range, then any wind component will reduce the distance to the furthest point from the departure point.

FIGURE 2-2
Maximum Range Speed



Maximum Endurance

19. Flying for endurance denotes remaining airborne for as long as possible, using the fuel available. Therefore, maximum endurance is obtained for a given quantity of fuel at the lowest rate of fuel consumption, i.e. the lowest fuel flow per unit of time. Wind has no effect on endurance or the speed to fly to obtain the maximum endurance.

20. If the airframe were the only consideration, maximum endurance would be obtained by flying at the condition that requires the minimum amount of work to be done to overcome drag per unit of time. As the rate of doing work is equal to power, then the best operating condition would be at the speed of minimum power, VIMP, which is slightly lower than VIMD. However, the airframe is not the only consideration because the efficiency of the power units must also be taken into account.

Piston/Propeller Power Units. The power output of a piston/propeller combination is approximately constant for a given fuel flow.

Power required = drag x airspeed.

But this power requirement increases with height because of the increased airspeed necessary to overcome a given amount of drag. It is, therefore, necessary to fly at low altitude to minimize drag and hence reduce the power required. Altitude does not significantly affect fuel flow.

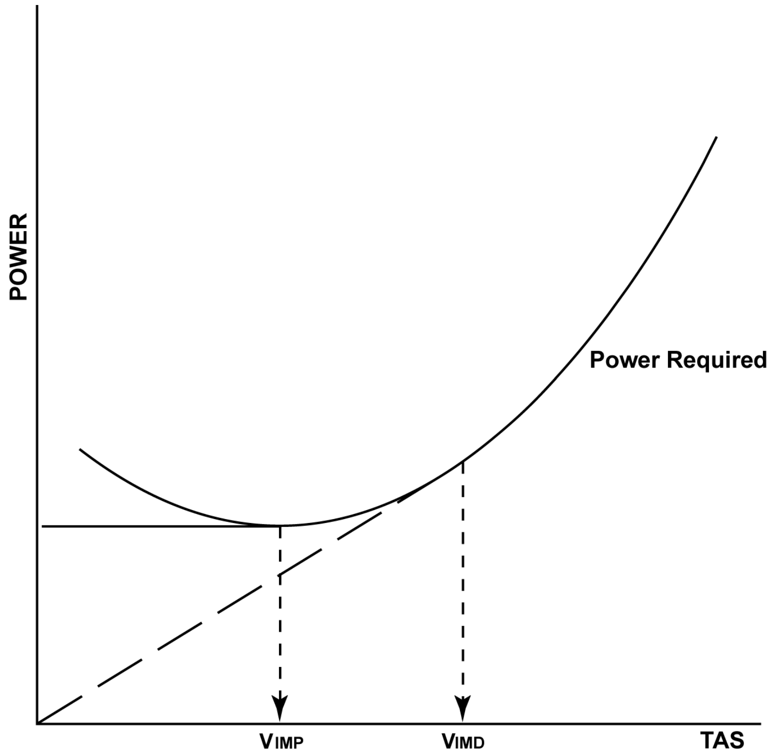
Figure 2-3 shows the piston/propeller power available curve has the greatest reserve of power available over power required to be VIMP. At this point the fuel flow is at the minimum possible. The IAS at VIMP is relatively low which makes accurate flying quite difficult. Consequently the manufacturers usually recommend a higher more comfortable speed or even the use of a small amount of flap to increase controllability. This adjustment ensures that any minor disturbance does not cause the IAS to drop to a point on the 'wrong' side of the drag curve. Thus, low IAS at low altitude and low RPM produce the best endurance.

Jet Power Units. Fuel flow for a turbo-jet is approximately proportional to the thrust produced, irrespective of speed or altitude. Since thrust required is equal to drag then the minimum thrust and hence the minimum fuel flow is at the point of minimum drag, VIMD. Therefore, maximum endurance is attained at VIMD. As drag and thrust are both constant at all altitudes, the fuel flow remains almost constant. In practice the fuel flow decreases very slightly at high altitude, because of the higher propulsive efficiency at high altitude resulting from the higher TAS and higher RPM.

Figure 2-3 shows that the reserve of power available above the power required remains constant for all speeds between VIMD and 1.2 VIMD.

The manufacturers usually recommend that, for maximum endurance, the speed should be above VIMD to improve the handling qualities, but at high altitude this increase should not be so high as to cause a significant increase in drag. Maximum endurance speed is always less than maximum range speed.

FIGURE 2-3
Maximum Endurance



Summary

21. The best conditions to attain maximum range or maximum endurance are:

Piston/Propeller Aircraft

(a) Maximum Range. VIMD at the most efficient altitude for the power units.

(b) Maximum Endurance. VIMP at the lowest practical altitude, at low RPM.

Jet Aircraft

(a) Maximum Range. VI/DMAX at the highest practicable altitude.

(b) Maximum Endurance. VIMD at the highest practicable altitude.

Surface Load Bearing Strength

Current Pavement Strength Reporting Method

Surface Load Bearing Strength

References: CAP 168 SECT II APPX A: ICAO ANNEX 14

1. The operation of aircraft from any type of airfield surface can never be safely undertaken without full details of the aircraft load characteristics and the surface strength being known. Forty years ago it was common practice for aerodrome operators to classify surfaces in broadly defined categories. Since then aircraft weights and tyre pressures have increased, and wheel arrangements changed, so much that the original categories have become meaningless.

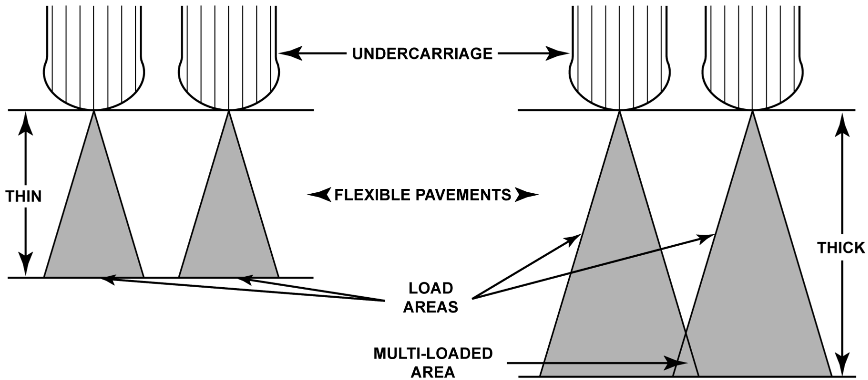
2. Although a simple system of load comparison between the aircraft and surface is necessary, it has to be accurate and easy to apply. Many tests were carried out using steel plates and known weights to compile surface failure/load tables. From these tests various systems have been developed to meet the requirements of modern aircraft.

3. In general, an aerodrome pavement should be strong enough for an aircraft to operate without risk of damage to either pavement or aircraft under normal circumstances. The system of load bearing comparison developed in the UK was accepted by ICAO, and is now one of the two methods in use throughout the world. Originally the systems was known as Load Classification Numbers (LCN) from which developed the Load Classification Group (LGG) system.

Pavement Types. Two main pavement types exist-'rigid' when the bearing strength is derived from a concrete slab and 'flexible' when the strength is obtained from a series of layers of compacted substance usually finished with a surfacing of bituminous material.

4. The strength of the surface is a measure of its load bearing capability. Flexibility or relative stiffness of the surface is related to the strength of the ground beneath the pavement and the thickness of the pavement. Rigid pavements have a measure of relative stiffness which is quoted in '1' inches and flexible pavements in 'h' inches.

FIGURE 3-1
The Effect of a Multi Wheeled Undercarriage



Stress Effects. The stress effect an aircraft has on a pavement varies with AUW, tyre pressure, number and spacing of wheels, type of pavement and the actual or equivalent thickness of that pavement. Aircraft with multi-wheel arrangements are better able to spread their load and are often less limited by thin flexible pavements than by thick ones, which may suffer a multi-loaded fracture area between the wheels at the base of the pavement. See Figure 3-1.

Surface Load Bearing Strength

Airfield Surface Weight Limitations. All airfield surfaces, including hard standings, parking areas, hangar floors, taxiways and runways, whether constructed of tarmac or concrete, are classified according to their strength. Each area is given the load classification number (LCN) or single wheel loading (SWL) or its weakest point. The LCN or SWL of the aircraft must not exceed the figures laid down by the airport authority at any point which the aircraft is likely to traverse before getting airborne.

Runway Surfaces. The surface of runways should be without irregularities that would cause loss of braking action, affect the aircraft steering or otherwise adversely affect the take-off or landing of an aircraft. The coefficient of friction in both wet and dry conditions must reach a satisfactory standard. If abnormal quantities of water are present on the runway the pilot must be notified of its depth and of its likely effect on braking action.

5. The surface areas beyond the end of the runway must be the same width as the runway and have a bearing strength not less than 30% that of the associated runway. The area up to 60 m. (200 ft.) beyond the runway or stopway end and 23 m. (75 ft) from each side of the runway and stopway, must be capable of bearing the maximum weight of all aircraft that it is intended to serve without causing significant damage to the aircraft. Beyond these limits the remainder of the runway strip is graded, but not prepared to the same standard. The bearing strength does not decrease until a distance of 45 m. (150 ft). from the runway centre line, and then at a gradual rate to assist in the arrest of the aeroplane. Runway extensions must always remain negotiable by Fire and Rescue vehicles.

Current Pavement Strength Reporting Method

6. All member States of ICAO are required by Annex 14 to promulgate their aerodrome pavement strengths in their individual AIPs. Of the pavement strength classification system currently in use, only four were acceptable to ICAO for the purposes of complying with this requirement. They were: the maximum gross aeroplane mass allowable, the maximum undercarriage leg load allowable, the load classification number (LCN) system and the load classification group (LCG) system. Freedom of selection between these four acceptable choices resulted in a variety of different systems being used by member States, and even between aerodromes of the same State. This situation complicated performance planning.

7. To resolve this problem and maximize the pavement surface life, it was decided by ICAO that a new method of reporting pavement strength should be adopted to replace the four existing acceptable methods. The new method is detailed in Amendment 35 to Annex 14 of ICAO Standard Practices. It introduced uniformity and standardization of pavement strength reporting and at the same time is easily used for all aircraft types.

8. The criteria developed from the load classification number (LCN) or load classification group (LCG) method will continue to be used for the design and evaluation of pavements. However, the original pavement strength classification was converted into units of the new reporting method by the aerodrome operating authority before being promulgated by the appropriate national civil aviation authority. It is therefore only the method of reporting pavement strength that is changed by the new system. The base datum used for the new reporting method is common to both pavement and aeroplane, so as to facilitate easy comparison. All civilian aeroplane types have already been classified by ICAO to this datum and a comprehensive list has been published in the amendment.

9. There are two basic procedures contained in Amendment 35. The first procedure is designed for use with pavements intended for aeroplanes having a maximum total weight authorized (MTWA) of 5700 Kgs (12,500 lbs) or less. The second procedure is used for reporting the strengths of all other pavements. Only the second procedure has been adopted by the CAA for implementation in the UK.

10. Pavement strengths reported in other member countries using the first procedure will contain a simple statement in words of the maximum allowable aircraft weight and the maximum allowable tyre pressure. No aeroplane having a weight and/or tyre pressure that exceeds the limiting pavement strength values so stated is permitted to use the pavement. An example of a report using the first procedure would appear in the AIP as 500 Kgs/0.45 MPa. (Note: 1 Megapascal (MPa) = 145 psi).

11. The second procedure is used for reporting the strength of those pavements intended for use by heavy aircraft. It was adopted by the CAA for use by civilian aerodromes and aeroplanes from 26 November, 1981. This reporting method is referred to as the Aircraft Classification Number – Pavement Classification Number (ACN/PCN) system. The pavement strength report using this system is divided into five parts, each of which is coded and promulgated in the AIP in a prescribed order to ensure that the decode is unambiguous.

12. The five parts of the report are: Pavement Classification Number (PCN). See Figure 3-2.

This is a number given to the pavement strength which expresses the relative effect of an aircraft upon the pavement for a specified sub-grade strength, and represents the bearing strength of the pavement for an UNRESTRICTED number of movements.

Classification numbers commence at zero and are on a continuous scale with no upper limit. A pavement load rating of one PCN is that strength which would be just sufficient to support a single wheel of mass 500 Kgs and tyre pressure of 1.25 Mpa (181.5 psi). Sample coded report: PCN 60.

Pavement Type. The reporting procedure for pavement type is divided into 'rigid' and 'flexible' – the same as that used for the evaluation of aircraft classification numbers. The type reported depends upon its relative stiffness. If the surface bearing strength is derived from a composite material or from layers of a compacted substance, the pavement type could fall in either category. If it is derived from a concrete slab, it is normally designated 'rigid'. The code used for the report is 'R' for rigid and 'F' for flexible.

Sub-Grade Strength Category. The strength of the pavement sub-grade is measured and classified in one of four groups for the appropriate pavement type and is either high, medium, low or ultra-low. These classifications are coded for the report as:

'A' – High; 'B' – Medium; 'C' – Low; 'D' – Ultra-Low;

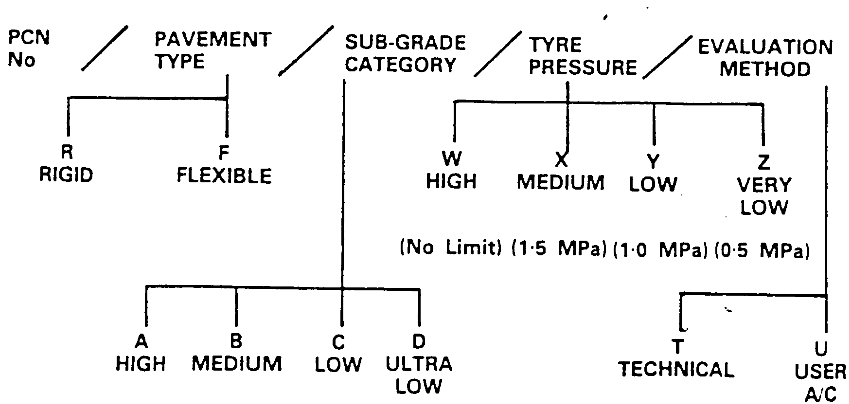
Tyre Pressure Category. Tyre pressures are arbitrarily divided into four groups and coded:

'W' – High tyre pressure with no upper limit.
'X' – Medium, maximum tyre pressure 1.5 MPa (217.5 psi)
'Y' – Low, maximum tyre pressure 1.0 MPa (145 psi)
'Z' – Very Low, maximum tyre pressure 0.5 MPa (72.5 psi).

Thus the maximum tyre pressure that a pavement can withstand is reported by the appropriate group code.

Evaluation Method. Only two methods may be used to determine pavement qualities. They are coded 'T' or 'U'. If a full technical evaluation of the pavement has been carried out, it is reported as 'T'. If the evaluation is based upon the experience gathered from user aircraft, it is reported as 'U'. This information is useful to manufactures and operators should it become necessary to study an aerodrome pavement in detail.

FIGURE 3-2
Current Pavement Strength Reporting Method (for pavements intended for heavy aircraft)



13. The introduction of the ACN/PCN reporting method has given the aerodrome operating authority greater freedom in deciding the maximum permissible aircraft weight than was possible before. In the past an aerodrome operating authority had to restrict the aircraft maximum weight to that which was determined by the LCG assessment method. Now, if the aerodrome operating authority so desires and considers it safe, it can permit the unrestricted movement of larger aircraft types by utilizing the 'U' symbol and reporting the limiting PCN equal to the upper ACN of the required aircraft type. Of course this may subsequently result in the PCN being lowered if the pavement performance does not meet with expectations and begins to deteriorate.

An example of pavement strength reported in the recommended manner is PCN 60/F/B/X/T which, when decoded, becomes:

Pavement Classification Number 60.

Flexible Pavement.

Medium Strength Sub-Grade.

Medium tyre pressure limited to 1.5 MPa (217.5 psi) Pavement characteristics were all evaluated technically.

14. An Aircraft Classification Number (ACN) is a number which expresses the relative effect of an aircraft mass upon a pavement of a specified sub-grade strength. A single wheel supporting a mass of 500 Kgs at a tyre pressure of 1.25 MPa (181.25 psi) is considered to have a load rating of 1 ACN. To enable a simple comparison to be made between aircraft mass and pavement strength ICAO have prepared a table of ACN's which include the majority of civilian aircraft types currently in use having an MTWA exceeding 5700 Kgs (12500lbs). MTWA is the maximum total weight authorized. Normally this is the maximum take off weight plus taxi fuel, i.e. maximum ramp weight.

15. The table was constructed to the same base datum as PCN and produced by means of a computer programme designed for the purpose. In future, aircraft manufactures will have to calculate ACN information for new aircraft types and publish it in the Flight Manual. A sample of the table produced by ICAO is at Figure 3-3.

16. Use of the table is relatively simple. Enter the line appropriate to the aircraft type and travel horizontally to intercept the pavement type block at the appropriate sub-grade strength category. Extract the upper and lower ACN's and interpolate for the actual ramp weight for departure or actual landing weight for arrival. The method of exact interpolation for weight is given on the following page.

17. Unless prior permission has been obtained from the aerodrome operating authority the ACN and tyre pressure for the actual weight must not exceed the maximum PCN and tyre pressure published in the AIP. Details of overload operating conditions are given later in this Chapter.

18. The Aircraft Classification Numbers table only quotes the numbers for each pavement type, and the sub-grade strength for two aircraft weights – maximum weight and the empty weight. To find the ACN for any weight between these two limiting weights it is necessary to complete the following calculation.

19. From the table against the appropriate aircraft type and in the column for the pavement type and sub-grade strength, extract the ACN for the maximum weight and for the empty weight, and note the aircraft tyre pressure.

$$ACN_{act} = ACN_{max} - \frac{(\text{Max Wt-Act Wt})\ (\text{ACN max-ACN empty})}{(\text{Max Wt-Empty Wt})}$$

20. For example a Boeing 737-100 using a rigid pavement with a medium strength sub-grade at an actual weight of 35.000 Kgs will be seen from Figure 3-3 to have an ACN max of 26 and an ACN empty of 13 at a tyre pressure of 1.02 MPa. Therefore:

$$ACN_{act} = 26 - \frac{(45722 - 35000) \times (26 - 13)}{(45722 - 25942)}$$

$$= 26 - \frac{(10722) \times 13}{(19780)}$$

$$= 26 - (0542 \text{ x } 13)$$

$$= 26 - 7.05 = 18.95$$

FIGURE 3-3

Aircraft Type	Maximum Take Off Mass/ Operating Mass Empty Kgs	Load On One Main Gear Leg	Tyre Pressure			ACN's Relative to Subgrade Category							
						On Rigid Pavements				On Flexible Pavements			
			MPa	psi	Kg/cm^2	High K=150	Med K=80	Low K=40	Ultra Low K=20	High CBR= 15%	Med CBR= 10%	Low CBR= 6%	U.Low CBR= 3%
A300 B2	142,000 85,690	46.5	1.23	179	12.58	37 19	44 22	52 26	60 30	40 21	45 23	55 26	70 35
B707-320B	148,778 64,764	46.0	1.24	180	12.65	39 14	46 15	55 18	63 20	42 15	47 16	57 17	73 23
B727-200 (Standard)	78,471 44,293	46.4	1.15	167	11.74	46 23	48 25	51 26	53 27	41 21	43 22	49 24	54 28
B737-100	45,722 25,942	46.3	1.02	148	10.40	24 12	26 13	28 14	29 15	22 12	23 12	26 13	30 15
B747-100	334,751 162,703	23.125	1.55	225	15.81	44 18	51 20	60 23	69 26	46 19	50 20	60 22	81 28
Concorde	185,066 78,698	48.0	1.26	183	12.86	61 21	71 22	82 25	91 29	65 21	72 22	81 26	98 37
DC-8-63	162,386 72,002	47.6	1.34	195	13.70	50 17	60 19	69 23	78 26	52 18	59 19	71 22	87 29
DC-9-41	52,163 27,821	46.65	1.10	160	11.24	32 15	34 16	35 17	37 18	28 13	30 14	33 15	37 18

21. A feature of the new reporting systems is that guidance is given on the criteria to be used by aerodrome authorities for regulating overload ensure that it can sustain a defined load for a specified number of movements, and that, save in the case of a massive overload, the pavement will not suddenly of catastrophically fail. Continuous operations with loads below the limiting PCN value will extend the design life of the pavement, but those operations with loads greater than the published PCN value will shorten the life. Aerodrome operating authorities may permit occasional operations when the ACN exceeds the PCN but should be aware that the pavement life expectancy will be slightly reduced and the surface deterioration slightly accelerated for each such movement.

22. The table at Figure 3-4 shows the conditions that will normally be used as a guide by aerodrome operating authorities.

Surface Load Bearing Strength

FIGURE 3-4
Conditions for Exceeding PCN

% ACN Exceeds PCN	Conditions To Be Satisfied Before Movement Can Be Considered Acceptable
10%	**a.** Pavement older than 12 months.
	b. No visible signs of pavement distress.
	c. Overload operations do not exceed. 5% Of the total annual movements.
	d. Overload operations are spread over the year.
10% - 25%	**e.** a. to d. inclusive, plus regular inspections by a competent person.
	f. Immediate curtailment of overload operations when signs of pavement distress become visible.
	g. Overload operations not resumed until pavement strengthening work is complete.
	h. Special circumstances only.
	j. Scrutiny of pavement records by a pavement engineer.
25% - 50%	**k.** Thorough inspection by pavement engineer before and after movement.
Over 50%	**l.** Emergency Movement Only.

Contaminated Surfaces

Contaminated Surfaces

1. The effect that contaminated surfaces have on the performance of an aircraft is different for each type because of weight, speed, tyre and undercarriage variations. If an aircraft is permitted to operate on contaminated surfaces, the Flight Manual will contain a statement to this effect giving any limitations and special handling techniques that may be necessary to ensure compliance with the appropriate regulations.

2. Most aerodrome authorities take action to minimize the effect of ice, snow and rain; but it is still necessary to measure the braking action on the surface. The most reliable and uniform method of providing this type of information is to measure the amount of friction on the surface. Not only the runways require testing, other surfaces such as holding bays, taxiways and aprons should be checked for satisfactory braking.

3. Various methods may be used to measure surface friction, which is considered to be the maximum value of friction afforded when a wheel is braked but is still rolling. The most suitable method of assessment is generally determined by operational considerations. The method used to measure surface friction, and then to report it, is of uniform type to enable pilots to correctly interpret the meaning of the value stated. The equipment used for this purpose provides continuous measurement of the maximum friction along the entire runway.

Braking Coefficient of Friction. Operationally, a pilot needs to know how his aeroplane will perform on a contaminated surface compared with how it would perform on a dry hard surface. Braking action information may be passed by R/T in descriptive terms or as a coefficient of friction, which is the tangential force applied by a surface, expressed as a proportion of the normal dry surface force upon a loaded, smooth-tyred aeroplane. The relationship between the braking coefficient of friction and the aircraft's groundspeed for a reference wet hard surface is derived in accordance with AMJ25X1591 paragraph 3.2.3 a. or b. The wheel is considered to be travelling parallel to the surface at a speed of slip which is close to the groundspeed.

Contaminated Surface Measurements. Before the airport operating authority declares a surface fit for use by aircraft, the depth of contaminant and the braking action have to be measured. The depth of snow or slush on the runway is measured with a standard depth gauge every 300 metres along the runway between 5 and 10 metres either side of the centre-line and clear of any ruts. The average reading of depth for each third of the runway is then promulgated. The depth of ice covering runways is not measured.

A continuous runway friction measuring trailer (Mu-meter) and a brake testing decelerometer (Tapley meter) carried in a light van or truck is used to measure the effect of ice, snow, slush and water on braking action.

Braking Action Assessment Methods. Assessment of braking action will be made by one of the following methods:

(a) **Continuous Recording Friction Measuring Trailer (Mu-meter).** This method employs a runway friction measuring trailer (Mu-meter) towed by a vehicle at 40 mph. The equipment provides a continuous register of the mean coefficient of friction values either on a paper trace or by means of a digital read-out that is used in conjunction with a hand computer. The principle employed in this case is the measurement of the side-force coefficient generated between the surface and a pair of pneumatic tyres set at a fixed toe-out angle. This device should normally indicate that a possibility of 'slushplaning' exists by giving a low value coefficient of friction.

(b) **Brake Testing Decelerometer (Tapley Meter).** An assessment is made of the coefficient of friction using a brake testing decelerometer carried in a van or light truck. The brakes are applied at 25 – 30 mph. The van or truck has standardized characteristics and a standard procedure to ensure uniformity in technique. The principle employed is the assessment of the coefficient of friction between skidding pneumatic tyres and selected points on the surface being tested.

This method is limited to use on ice (gritted or ungritted) and dry snow, because it is likely to produce misleading high readings in slush, wet snow or water (for example, it will not detect that there is a possibility of 'slushplaning'). Braking action therefore will not be assessed in the latter conditions. Most major airfields use the Mu-meter as the prime method of measurement with the Tapely meter as a back-up. Minor airfields may only use the Tapely meter for measuring braking action. Tests for braking action are made along the full length of the runway and stopway approximately 10 metres either side of the centre-line in two runs. Average readings for each third of the runway length are then promulgated. Decelerometer tests are made every 300 metres along the runway. Mu-meter readings which do not fall below .50 for any third of the runway are not normally passed to the pilot unless specifically requested.

Improvement of Braking Action. To increase the friction value of aircraft maneuvering areas affected by ice or snow, grit may have to be put on the surface if poor braking conditions persist. The specification of grit used is the best compromise between improving friction and causing least damage to aircraft. The risk to aircraft when using reverse thrust or pitch is high, and extreme caution is necessary particularly after a sudden thaw.

Reporting Braking Action to the Pilot

4. When the Mu-meter reading for any one-third of the runway falls below 0.50 but not below 0.40, a single mean value for the whole runway will be passed by R/T to the pilot. This is preceded by the corresponding qualitative term and by a descriptive term of the conditions.

EXAMPLE 4-1

EXAMPLE

Braking action medium 0.46.
Heavy rain.
Time of measurement 1030".

5. Should the value for any one-third fall below 0.40 then the values for each third will be given in order starting with the one nearest the threshold, preceded by the qualitative term appropriate to the whole runway and followed by a descriptive term of the conditions

EXAMPLE 4-2

EXAMPLE

Braking action poor 0.46 0.37 0.39.
Standing water.
Time of measurement 1530".

Interpretation of Braking Action Assessments

6. For take-off, as for landing, the aerodrome authorities measure the runway surface coefficient of friction and estimate the braking action required. The reported braking action passed to the pilot is that of a vehicle unaffected by any condition other than that of the surface. It is therefore the pilot who must use his judgement of the other factors affecting the aircraft, such as crosswind and AUW, to place the appropriate interpretation on the reported conditions. A broad guide (which should nevertheless be used with discretion) is as follows:

Good: Aircraft pilots can expect to take-off and/or land within the scheduled wet distances without undue directional control or braking difficulties caused by the runway conditions. Untreated ice does not come into this category but gritted ice could produce the friction required.

Medium: Aircraft are likely to use all of the wet scheduled distance, including the safety factor part of the distance. Directional control may be impaired. The achievement of satisfactory landing performance depends on the precise execution of the recommended flight technique.

Poor: The pilot must expect the aircraft to run at least the full 'very wet' or aquaplaning distance, where this too is scheduled. There may be a significant deterioration in braking performance and in directional control. It is advisable to ensure that the landing distance specified in the Flight Operational Manual for very wet conditions does not exceed the landing distance available.

International Measurement of Runway Surface Conditions

7. There are several methods used to measure runway surface conditions throughout the world. These measurements can then be reported to the pilot using any one of a number of different ways. **Caution, although the terminology used in Europe and North America is similar it may be interpreted differently.** Consequently it can be difficult to correctly interpret the meaning of the report.

Surface Contaminants

Dry Snow. Loose hard snow is usually in the form of dry pellets which can be blown, or if compacted by hand, will fall apart again upon release. For this contaminant to be present the temperature must be below –5°C (and not risen since the snow fell). Its specific gravity is up to but not including .35. The maximum permissible depth for take-off or landing is 60mm on any part of the runway, measured by ruler.

Wet Snow. Loose snow taking the form of large flakes which if compacted by hand will stick together to form a snowball (it forms a white covering on all surfaces which when stamped upon does not splash up). The temperature for this type of snow is between -5°C and –1°C, with a specific gravity of .35 up to but not including .5.

For take-off and landing the maximum permissible depth is 15mm. A rough guide to this depth is the same as the welt of a shoe.

Compacted Snow. Snow which has been compressed into a solid mass and resists further compression is compacted snow. It will hold together or break into lumps if picked up. This type of covering is normally caused by the transit of vehicles over the surface when snow is falling. Its specific gravity is .5 and over.

Slush. A mixture of water and snow which is displaced with a splatter when a heel-to-toe slapping motion is made on the ground. The temperature is at or around 0°C. A maximum depth of 15mm is permissible for take-off and landing. Specific gravity is .5 up to .8.

Water. Visible puddles, usually of rain, standing on the surface causing paved surfaces to glisten when the temperature is above 0°C. On a natural surface it is assumed that more than 3mm of water exists if under a firm foot pressure the water rises to the surface.

Mixtures. Mixtures of ice, snow and/or standing water may, especially when rain, sleet or snow is falling, produce a substance having an SG above .8. This substance is transparent at higher SG's, and is easily distinguished from slush, which is cloudy.

Ice. A frozen layer of surface moisture. The thickness of which varies and produces a poor coefficient of friction according to the condition of the surface.

Water Equivalent Depth (WED)

8. The limitations and corrections given in most Flight Manuals are calculated for a uniform layer of contaminant at the maximum permissible depth and Specific Gravity quoted in the Table at Figure 4-1. Flight Manuals that do contain this information express the correction in terms of **Water Equivalent Depth (WED); which is the contaminant depth multiplied by its Specific Gravity.** Because WED values are not available to aircrew, operators quote the limitations and corrections in the Operations Manual in terms of contaminant depth. Estimated data is not acceptable for WED's exceeding 15mm. *ACJ 25.113(a)(3)2*. Figure 4-2 enables WED to be converted to contaminant depth and utilises the details given in Figure 4-1.

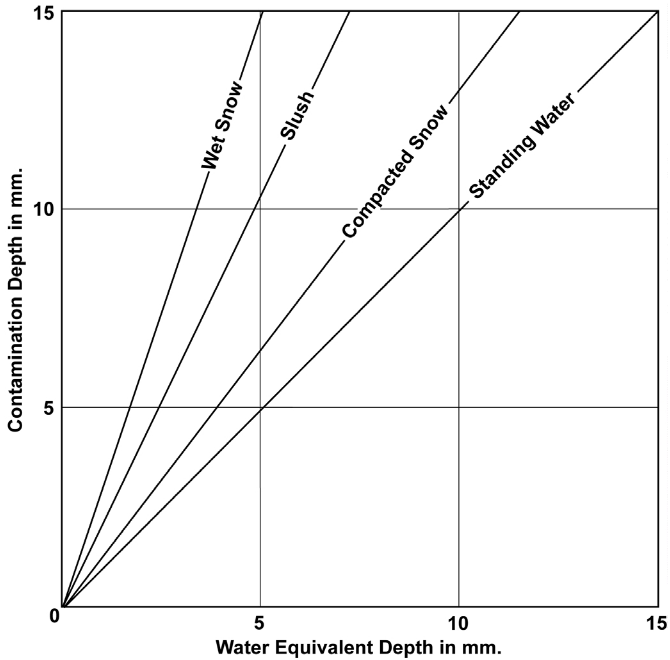
FIGURE 4-1
Contaminant Limitations Reccomended by the CAA

CAA AIC 61/1999 (Pink 195) Paragraph 2.1.1.

Contaminant	SG	Max. Depth	WED
Very Dry Snow	<0.35	80mm	<28
Dry Snow	<0.35	60mm	<21
Wet Snow	0.35 to 0.5	15mm	5.25 to 7.5
Comp. Snow	0.5<	15mm	>7.5
Slush	0.5 to 0.8	15mm	7.5 to 12
Standing Water	1.0	15mm	15

Contaminated Surfaces

FIGURE 4-2
Conversion from WED to Contaminant Depth



Contaminated Runway

9. A contaminated runway is defined in *JAR-OPS 1.480 (a.) (2)* is one on which more than 25% of the runway surface area (whether in isolated areas or not) within the required length and width being used is covered by any of the following:

(a) Surface water more than 3mm (0.125ins.) deep, or by slush or loose snow, equivalent to more than 3mm (0.125ins.) of water;

(b) Snow which has been compressed into a solid mass which resists further compression and will hold together or break into lumps if picked up (compacted snow) or

(c) Ice including wet ice.

Damp Runway

10. A damp runway is defined in *JAR-OPS 1.480 (a) (3)* is one on which the surface is not dry, but when the moisture on it does not give it a shiny appearance. For performance purposes, a damp runway, other than a grass runway, may be considered to be dry. **[JAR-OPS 1.475 (d)].**

Dry Runway

11. A dry runway is defined in *JAR-OPS 1.480 (a) (4)* as one which is neither wet nor contaminated, and includes those paved runways which have been specially prepared with grooves or porous pavement and maintained to retain 'Effectively Dry' braking action when moisture is present.

Wet Runway

12. A wet runway is defined in *JAR-OPS 1.480 (10)* as one on which the surface is covered with water, or equivalent, less than 3.mm (0.125ins.) or when there is sufficient moisture on the surface to cause it to appear reflective, but without significant areas of standing water.

Flooded Runway

13. Extensive patches of standing water are visible.

NOTE:

Flooded will be reported when more than 50% of the assessed area is covered by water more than 3mm deep.

Contaminated Runway Calculations

14. Most modern aeroplanes are certicated using dry runway performance data. However, provision for operations on a contaminated wet surface is provided for in *JAR-25 AMJ 25X1591* and is required by *JAR-25X1591*. The method used by the manufacturers to determine this data is similar to that used to determine dry runway data except V1 (decision speed) cannot be scheduled because of the indeterminate friction characteristics of the surface. Hence any information or data provided in the Flight Manual is of an advisory nature only.

Hydroplaning (Aquaplaning)

15. The tyre friction required by an aeroplane to maintain directional control and effective braking is a finite quantity for each aircraft type. The amount of friction actually obtained can be adversely affected by any surface contaminant. Water is particularly dangerous because it can cause an almost total loss of tyre friction. Such a condition is referred to as hydroplaning or aquaplaning. It is the condition which exists when the tyre footprint, the contact area, is lifted from the surface by fluid pressure until it rides on top of the fluid film. The result is negligible braking and difficulty in maintaining directional control.

16. The effects of aquaplaning on aircraft handling characteristics are similar to those experienced on an icy or very slippery surface. Some Flight Manuals contain information on handling characteristics and aircraft performance when such surface conditions exist. The guidance given should be used at all times when the contaminant depth is 'significant'. Some degree of hydroplaning is possible at any time when the runway is contaminated by water or some other foreign substance.

17. Two types of hydroplaning can occur, either individually or together, on wet or icy runways. They are known as DYNAMIC and VISCOUS, and they differ in their initial cause and total duration.

Dynamic Hydroplaning. For this phenomenon to occur, two essential conditions must be present. First, the surface must be flooded to a depth which exceeds the total depth of the runway texture plus the tyre tread. This is the critical depth and is normally 3 mm. The second condition is that the aircraft must be travelling at or above the critical speed, which is the tyre speed at which the standing inertia of the water is such that the water is unable to escape from under the tyre. If both conditions are present, dynamic hydroplaning is likely to occur.

18. It has been determined by research that the size of the tyre footprint directly affects the aircraft's hydroplaning characteristics. If the tyre is correctly inflated, its footprint is unaffected by changes in AUW. But if the tyre is under-inflated, the size of the footprint is increased irrespective of the AUW. An under-inflated tyre is more likely to hydroplane than one that is correctly inflated, and it will do so at a lower groundspeed than that at which hydroplaning would normally occur. It therefore follows that to reduce the risk of hydroplaning it is good airmanship to ensure that the aircraft tyres are in good condition, have adequate tread and are inflated at the correct pressure. If a choice of tyres that can be fitted exists, multi-rib tyres should be selected because they delay the onset of aquaplaning.

19. The airfield operating authorities, during the construction or repair of runways, can assist the pilot by delaying the onset or even preventing hydroplaning by ensuring the runways are porous or grooved to give better tyre traction and that there is adequate drainage to prevent build up of moisture. However, strong crosswinds can defeat good drainage on the windward side of the runway. Aircraft manufacturers during aircraft design can also assist by incorporating tandem wheel arrangements because they can travel through greater depths of contaminant with less difficulty than others.

20. Dynamic hydroplaning after its onset. will continue whilst the two essential conditions are maintained. If either the groundspeed falls below the critical speed or the water depth reduces below the critical depth, this type of hydroplaning will not persist.

21. The speed at which braking efficiency begins to deteriorate is indeterminate because it is a gradual process, but the speed at which it becomes total can be determined. Tests carried out with an aircraft fitted with bald tyres, on a smooth, wet surface revealed that the speed at which hydroplaning occurred can be calculated from the following formula:

$$\text{For a non-rotating tyre } V\rho(\text{spin up}) \text{ in knots } = \frac{7.7\sqrt{\rho}}{\sigma}$$

$$\text{For a rotating tyre } V\rho(\text{spin down}) \text{ in knots } = \frac{9\sqrt{\rho}}{\sigma}$$

(AMJ 25X1591Paragraph 4.3.0)

22. Where Vρ is the aquaplaning speed in knots and P is the tyre pressure in pounds per sq. in σ is the specific gravity of the precipitation.

23. On take-off, the tyre commences to roll on a wet surface, and at slower speeds the water present is able to escape to the sides of the tyre until the speed approaches the critical speed. At this point a wedge of water builds up in front of the tyre and lifts it clear of the surface. To avoid hydroplaning during take-off do not attempt to roll unless the water depth is less than critical for the entire length of the take-off run required.

24. For landing the non-rotating formula should be used to calculate the dynamic hydroplaning speed. It the depth of contaminant exceeds the critical depth, the landing should be delayed until it has drained below the critical depth. The keyword in these circumstances is CAUTION.

25. Remember the old maxim that a good landing is the result of a good approach. Make every attempt to obtain an accurate touchdown speed. Every 1% increase in touchdown speed above that recommended for the aircraft weight increases the landing distance required by 2%.

FIGURE 4-3
Example Dynamic Hydroplanning Speeds

Aircraft Type	Tyre Pressure		Tyre Hydroplaning Speed in Kts.	
	Mpa	Psi	Non-Rotating	Rotating
A300 B2	1.23	178.4	103	120
B707-320B	1.24	179.8	103	121
B727-200	1.15	166.8	99	116
B737-100	1.02	147.9	94	109
B747-100	1.55	224.8	115	135
Concorde	1.26	182.8	104	122
DC8-63	1.34	194.4	107	125
DC9-41	1.10	159.5	97	114

Viscous Hydroplaning. The only essential condition for viscous hydroplaning to occur is a smooth surface covered by a thin film of moisture. It happens at much lower groundspeeds than dynamic hydroplaning and is usually of very short duration. On normal landings at the touchdown point the aircraft tyres slip and skid momentarily until they spin up to their rotational speed. Usually the texture of the runway surface is coarse enough to break up the liquid film, but any deposits of rubber or oil prevent this dissipation taking place. The heat generated by the initial slippage of the tyre is enough to cause a thin layer of rubber to melt and adhere to the runway.

26. Successive landings cause the deposits to form a rubber sheet at the runway ends which reduces braking efficiency by 65% in hot weather up to 100% if the surface is wet.

Combined Hydroplaning. The loss of tyre friction on wet or flooded runways is generally the result of the combined effects of dynamic and viscous hydroplaning. If dynamic hydroplaning is predominant the area of the tyre under which the bulk of the water is trapped enlarges as the speed increases. If the contaminant is of less than critical depth, however, and there is no bulk of water present, the major part of the footprint is in contact with a thin film of moisture and viscous hydroplaning is the controlling element in contact with a thin film of moisture and viscous hydroplaning is the controlling element. Example of hydroplaning speeds are shown in the table at Figure 4-3.

Reverted Rubber Skids. When a tyre is hydroplaning, although the friction available is insufficient to rotate the wheel it does generate sufficient heat, on high pressure tyres, to melt the rubber at the contact point and wear a flat spot on the tyre. The heat also converts water or ice on the runway in the path of the tyre into steam. The tyre therefore rides on a layer of steam. This is particularly dangerous not only because of the ineffectiveness of the brakes but also because of the loss of directional control when the wheels are in a locked condition. Avoidance of reverted rubber skids, as they are called, depends on the pilot using the anti-skid systems of the aircraft to their maximum advantage, and calls for the application of skilful take-off and landing technique

Aeronautical Information Circular

AIC 61/1999 (Pink 195)

Risks and Factors Associated with Operations on Runways Contaminated with Snow, Slush or Water

Introduction

27. Operations from contaminated runways, by all classes of aeroplane, should be avoided whenever possible.

28. Major UK aerodromes make every effort, within the limits of manpower and equipment available, to keep runways clear of snow, slush and its associated water, but circumstances arise when complete clearance cannot be sustained. In such circumstances, continued operation involves a significant element of risk and the wisest course of action is to delay the departure until conditions improve or, if airborne, divert to another aerodrome.

Operational Factors

29. At major UK and Western European aerodromes, when clearing has not been accomplished, the runway surface condition is reported by the following method which is described in the UK AIP section AGA 5, United Kingdom Snow Plan. The depth of snow or slush is measured by a standard depth gauge, readings being taken at approximately 300 metre intervals, between 5 and 10 metres from the runway centreline and clear of the effects of rutting. Depth is reported in millimetres for each third of the runway length.

30. A subjective assessment is also made of the nature of the surface contaminant, on the following scale:

a)	Dry Snow	less than 0.35 Specific Gravity
b)	Wet Snow	0.35 to 0.50 Specific Gravity
c)	Compacted Snow	over 0.50 Specific Gravity
d)	Slush	0.50 – 0.80 Specific Gravity
e)	Standing Water	1.00 Specific Gravity

31. The presence of water on a runway will be reported to the pilot using the following description:

(a) Damp - The surface shows a change of colour due to moisture.

(b) Wet - The surface is soaked but no significant patches of water are visible.

(c) Water Patches - Significant patches of standing water are visible.

(d) Flooded - Extensive standing water is visible.It should be assumed that runway contamination exists unless the report indicates either condition (a) or (b) above is reported.

32. Depths greater than 3mm of water, slush or wet snow, or 10mm of dry snow, are likely to have a significant effect on the performance of aeroplanes. The main effects are:

(a) Additional drag – retardation effects on the wheels and spray impingement drag;

(b) Possibility of power loss or system malfunction due to spray ingestion or impingement;

(c) Reduced wheel-braking performance – the problems of aquaplaning;

(d) Directional control problem;

(e) Possibility of structural damage.

33. A water depth of less than 3mm is normal during and after heavy rain and in such conditions, no corrections to take-off performance are necessary other than the allowance, where applicable, for the effect of a wet or slippery surface. However, on such a runway where the water depth is less than 3mm and where the performance effect (a) is insignificant, isolated patches of standing water or slush of depth in excess of 15mm located in the latter part of the take-off run may still lead to ingestion and temporary power fluctuations which could impair safety.

34. A continuous depth of water greater than 3mm is unlikely as a result of rain alone, but can occur if torrential rain combines with a lack of runway camber/crossfall or a crosswind to reduce the rate of water drainage from the runway. In such conditions the water depth is unlikely to persist for more than about 15 minutes after the rain has ceased and take-off should be delayed accordingly.

35. In assessing the performance effect of increased drag (for reasons outlined previously), the condition of the upwind half of the take-off runway is most important, i.e. the area where the aeroplane is travelling at high speed. Small isolated patches of standing water will have a negligible effect on performance, but if extensive areas of standing water, slush or wet snow are present and there is doubt about the depth, take-off should not be attempted.

36. It is extremely difficult to measure, or predict, the actual coefficient of friction or value of displacement and impingement drag associated with a contaminated runway. It follows that aeroplane performance relative to a particular contaminated runway cannot accurately be schedule and that any 'contaminated runway' data contained in the Flight Manual can only be regarded as the best data available on aeroplane behaviour in circumstances when accurate prediction is impossible. It must be clearly understood that for all aeroplanes, including those in Performance Class A, there may be a time interval during the take-off when, in the event of an engine failure, the aeroplane has neither the capability to continue the take-off nor to stop within the remaining runway length. The duration of any risk period which may exist is variable and difficult to measure because of the lack of precise knowledge of acceleration or stopping performance in slush, standing water or snow. If the take-off weight is reduced, however, it is possible to achieve some reduction in the risk period in a particular set of circumstances.

37. The provision of performance information for contaminated runways should not be taken as implying that ground handling characteristics on these surfaces will be as good as can be achieved on dry or wet runways, in particular, in crosswinds and when using reverse thrust. Remember, the use of contaminated runway should be avoided if at all possible. A short delay in take-off or a short hold before landing can sometimes be sufficient to remove the contaminated runway risk. If necessary a longer delay or diversion to an airport with a more suitable runway should be considered.

General Limitations for Take-Off

38. When operations from contaminated runways are unavoidable the following procedures may assist:

(a) Take-offs should not be attempted in depths of dry snow greater than 60mm or depths of water, slush or wet snow greater than 15mm. If the snow is very dry, the depth limit may be increased to 80mm. In all cases the AFM limits, if more severe, should be observed.

(b) Ensure that all retardation and anti-skid devices are fully serviceable and check that tyres are in good condition.

(c) Consider all aspects when selecting the flap/slat configuration from the range permitted in the Flight Manual. Generally greater increments of flaps/slats will reduce the unstick speed but could increase the effect of impingement drag. Appropriate field length performance corrections should be made (see paragraph below).

(d) Fuel planning should include a review of the operation; including whether the carriage of excess fuel is justified.

(e) Ensure that de-icing of the airframe and engine intakes, if appropriate, has been properly carried out and that the aircraft is aerodynamically clean at the time of take-off.

(f) Pay meticulous attention to engine and airframe anti-ice drills.

(g) Do not attempt to take-off with a tailwind, or if there is any doubt about runway conditions, with a crosswind in excess of the slippery runway crosswind limit. In the absence of a specified limit take-off should not be attempted in crosswinds exceeding 10 kt.

(h) Taxi slowly and adopt other taxiing techniques which will avoid snow/slush adherence to the airframe or accumulation around the flap/slat or landing gear areas. Particularly avoid the use of reverse thrust, other than necessary serviceability checks which will be carried out away from contaminated runway areas. Be cautious of making sharp turns on a slippery surface.

(i) Use the maximum runway distance available and keep to a minimum the amount of runway used to line up. Any significant loss should be deducted from the declared distances for the purposes of calculating the RTW.

(j) Power setting procedures appropriate to the runway condition as specified in the AFM should be used. rapid throttle movements should be avoided and allowances made for take-off increases.

(k) Normal rotation and take-off safety speeds should be used, (e.g. where the Flight Manual includes data for the use of overspeed procedures to give improved climb performance, these procedures should not be used). Rotation should be made at the correct speed using normal rate to the normal altitude.

(l) Maximum take-off power should be used.

39. The design and Manufacturing Standards Division of the Civil Aviation Authority will advise on the safety of any proposed changes to the above procedures.

40. Aircraft Commanders should also take the following factors into account when deciding whether to attempt a take-off:

(a) The nature of the overrun area and the consequences of an overrun off that particular runway.

(b) Weather changes since the last braking and contaminant depth report, particularly precipitation and temperature, the possible effect on stopping or acceleration performance and whether subsequent contaminant depths exceed Flight Manual limits.

Landing

41. Attempts to land on heavily contaminated runways involve considerable risk and should be avoided whenever possible. If the destination aerodrome is subject to such conditions, departure should be delayed until conditions improve or an alternate used. It follows that advice in the Flight Manual or Operations Manual concerning landing weights and techniques on very slippery or heavily contaminated runways is only there to enable the Commander to make a decision, when airborne, as to his best course of action. Depths of water or slush, exceeding approximately 3mm, over a considerable proportion of the length of the runway, can have an adverse effect on landing performance. Under such conditions aquaplaning is likely to occur with its attendant problems of negligible wheel-braking and loss of directional control. Moreover, once aquaplaning is established it may, in certain circumstances, be maintained in much lower depths of water or slush. A landing should only be attempted in these conditions if there is an adequate distance margin over and above the normal Landing Distance Required and when the crosswind component is small. The effect of aquaplaning on the landing roll is comparable with that of landing on an icy surface and guidance is contained in some Flight Manuals on the effect on the basic landing distance of such very slippery conditions. The CAA Safety Regulation Group will give guidance, if required, where the Flight Manual does not contain information on the Landing Distance Required on an icy runway.

Aerodrome Surface Dimensions

Aerodrome Surface Dimensions

Distances Available

1. Available distances are those published in the AIP & NOTAMS, and depicted at Figure 5-1 and Figure 5-2.

Take-Off Run Available

2. Defined in JAR OPS 1.480 Paragraph a (9) as the distance from the point on the surface of the aerodrome at which the aeroplane can commence its take-off run to the nearest point in the direction of take-off at which the surface of the aerodrome is incapable of bearing the weight of the aeroplane under normal operating conditions. That is the gross weight of the aeroplane which includes everything and everyone carried in or on it at the commencement of the take-off run. CAP 168 Chapter 3 paragraph 13.1(a) states in most cases it will correspond to the length of the runway pavement. ICAO Annex 6 Page 44 states that it is the length of runway declared available and suitable for the ground run of an aeroplane taking off.

Load Bearing Strength. The runway must have a uniform characteristic of load bearing strength.

Braking Capacity. The runway is periodically checked to ensure the friction characteristics do not fall below an acceptable level, usually considered to be μ 0.5.

Runway Slope. The maximum slope at large aerodromes will not exceed ± 1% in UK or ± 2% in Europe. It will be free of irregularities which may cause undesirable bouncing, pitching or vibration or adversely affect braking efficiency.

Width. Only the full load bearing strength will be promulgated.

Runway Alignment Reduction. This the distance required by certain types or large aeroplane to line-up and is subtracted from TORA.

Obstructions. WIP may cause TORA to be temporarily reduced and will be notified by NOTAM. The proximity of uncontrolled roads or railways may cause a permanent distance reduction.

Stopway

3. Defined in CAP168 Section 3 paragraph 8 as an area on the ground beyond the end of TORA which is prepared and designated as a suitable area in which the aeroplane can be stopped in the event of an abandoned take-off. It is regarded as being provided for infrequent use and does not need the same bearing or wearing qualities as the runway with which it is associated.

Bearing Strength. Sufficient to support the aeroplanes it is intended to serve without causing structural damage to those aeroplanes.

Width. No less than the runway with which it is associated.

Braking Capacity. The friction characteristics of the stopway should not be substantially different to that of the runway. As recommended in ICAO Annex 14.

Slope. The slope should be the same as the runway and should not change by more than 0.5% per 30 m

Length Limitation. By one of the following:

(a) Deterioration of Load Bearing Strength.

(b) Deterioration of Friction Characteristic.

(c) Ditch.

(d) Depression.

(e) Obstacle liable to cause structural damage to an aeroplane if the take-off is abandoned.

4. Because it is considered to be for infrequent use it does not have to be maintained to the same standard nor swept as frequently as the runway. In winter it is often not cleared of snow. If the stopway is grass surfaced and is associated with a hard surfaced runway most operators of large public transport aircraft will refrain form using it in their take-off calculations. They prefer to accept a lower TOW than take the risk that in the event of an abandoned take-off the aeroplane may be damaged by sinking in the stopway turning an incident into an accident, or that the coefficient of friction may be substantially lower than that of the runway.

Accelerate/Stop Distance Available (ASDA)

5. The accelerate/stop distance available (ASDA) is defined in *JAR-OPS 1.480 (a) (1)* as:

6. The length of TORA plus the length of stopway, if such stopway is declared available by the appropriate authority and is capable of bearing the mass of the aeroplane under the prevailing operating conditions. It is often referred to as the emergency distance available either EMDA or EDA. This description is also given in CAP 168 Chapter 3 Paragraph 13.1 (b) and ICAO Annex 6 Part1.

7. An accurate description would be the distance from the point on the surface of the aerodrome at which the aeroplane can commence its take-off run to the nearest point in the direction of take-off at which the aeroplane cannot roll over the surfaces of the aerodrome and be brought to rest in a emergency without the risk of accident.

Clearway

8. Defined in CAP 168 Chapter 3 Paragraph 9. It is an area provided for the end of TORA which is free of objects above an upward slope of 1.25% from end of TORA which may cause a hazard to aeroplanes in flight (threshold lights less than 26 ins (0.66 m) do not have to be accounted. It provides an area over which an aeroplane can safely transit from lift-off to screen height. It needs no load bearing strength any may be land over or water.

Width. A clearway should extend laterally to a distance of at least 76 m on each side of the extended runway centre-line. JAR 1 and ICAO Annex 14 chapter 3 paragraph 3.5.3. In the UK CAP 168 defines the width in chapter 3 paragraph 9.2.1. As at the end of TORA not less than the width of the runway strip for the visual runway, which is 75 m. From the centre-line, expanding linearly to a semi-width of 90m. By the end of the clearway. On the type 'A' aerodrome obstruction chart an oblong of 90 m. Semi-width is used.

Length. This is defined in CAP 168 Chapter 3 Paragraph 9.3. As the least of either the distance to the first upstanding obstacle, excluding lightweight, frangible objects of 0.9 m or less in height or 50% TORA. ICAO Annex 14 states the length should not exceed half the length of TORA.

Take-off Distance Available (TODA)

9. This is defined in *JAR-OPS 1.480 Paragraph (a) (7)* as:

10. The take off distance available means either the distance from the point on the surface of the aerodrome at which the aeroplane can commence its take off run to the nearest obstacle in the direction of take off projecting above the surface of the aerodrome and capable of affecting the safety of the aeroplane, or one and one half times the take off run available, whichever is the less.

11. CAP 168 chapter 3 paragraph 13(c) describes TODA as the length of TORA plus the associated clearway. The same definition is also in ICAO Annex 14.

12. Thus TODA is limited in length by the first upstanding non-frangible obstacle liable to damage the aircraft in flight or to 150% TORA, whichever is less.

Landing Distance Available (LDA

13. Landing Distance Available (LDA) is defined in *JAR-OPS 1.480 (a) (5)* as the length of runway which is declared available by the appropriate authority and suitable for the ground run of an aeroplane landing.

14. The landing distance available means the distance form the point on the surface of the aerodrome above which the aeroplane can commence its landing, having regard to the obstructions in its approach path, to the nearest point in the direction of landing at which the surface of the aerodrome is incapable of bearing the weight of the aeroplane under normal operating conditions or at which there is an obstacle capable of affecting the safety of the aeroplane;

15. CAP 168 Chapter 3 Paragraph 13.1 (d) describes LDA as the runway length available and suitable for the ground landing run of an aeroplane.

Obstacle. All fixed (whether temporary or permanent) and mobile objects, or parts there of, that are located on an area intended for the surface movement of aircraft or that extend above a defined surface intended to protect aircraft in flight. Annex 14.

Temporary Obstacles. To be notified by ATC and NOTAM and the promulgated distances amended accordingly.

Frangibility. The characteristic of an object to retain its structural integrity and stiffness up to a predetermined maximum load, but on impact from a greater load, to break, distort or yield in such a manner to present the minimum hazard to aircraft. Annex 14.

Frangible Obstacle. An obstacle which when struck by a load greater than its predetermined maximum load will break, distort or yield.

Aerodrome Surface Dimensions

FIGURE 5-1

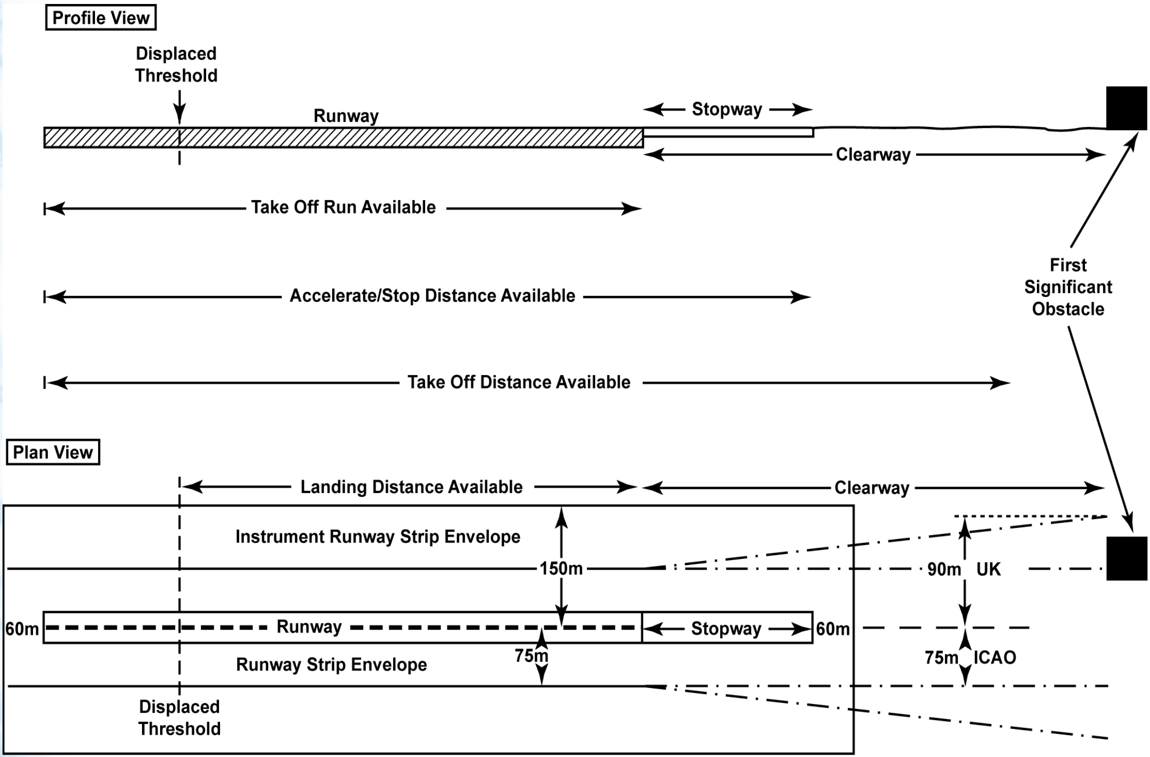
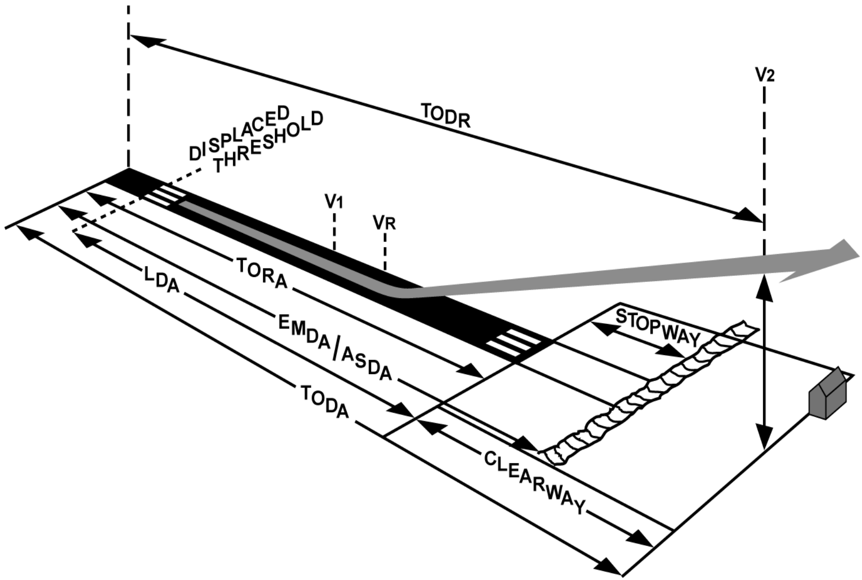


FIGURE 5-2

Available Distances Diagrammatically



Runway Alignment Reduction

16. *JAR-OPS 1.490 (c) (b)* requires that the published distances available be reduced by the amount taken by an aeroplane to line up with the runway. This correction is to be made before computation of the take-off performance. The amount of reduction is dependent on the runway turn geometry and the aircraft type.

17. The adjustment to TODA is based on the distance from the commencement of TODA to the main wheels position after line up. This is because the take-off distance required is measured from the start of the take-off to the point at which the aeroplane reaches screen height with the undercarriage extended. The TORA is reduced by the same amount because the take-off run required is the distance from the start of the take-off run to the point where the main wheels leave the ground. See Figure 5-4.

18. However, the adjustment to ASDA is based on the position of the nose wheel after line-up. This is because in the event of an abandoned take-off the nose wheel must come to rest before the end of the stopway.

19. Manufactures publish the distances taken to line-up for 180° and 90° turns on to the centre-line. In assessing the distance corrections a minimum edge safety distance (SD) is used which is specified in ICAO Annex 14. For the example aircraft quoted below the Boeing 737-400. This is 3.04m and for the 747 and 777-200 is 4.57m. See Figure 5-3, Figure 5-5, Figure 5-6 and Figure 5-7.

FIGURE 5-3

Example Runway Alignment Reductions

TURN	180° TURN ROUND			90° TURN ON	
AIRCRAFT TYPE	CORRECTIONS		R/W WIDTH	CORRECTIONS	
	TORA/TODA	ASDA	MIN	TORA/TODA	ASDA
737 – 400	-18.1 m	-32.4 m	27.7 m	-10.1 m	-24.3 m
747 ALL	-32.4 m	-56.4 m	70.7 m	-23.9 m	-49.5 m
747 SP	-47.7 m	-71.7 m	60 m	21.3 m	41.8 m
777 - 200	-32.9 m	-58.0 m	68.8 m	23.6 m	-49.5 m
777 – 300	-46.5 m	-71.6 m	60 m	26.2 m	57.4 m

FIGURE 5-4

Adjustments to Available Distances

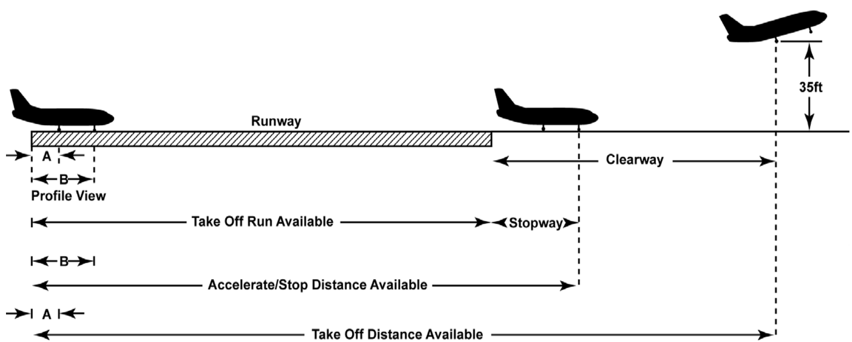


FIGURE 5-5
90 Degree Turn
Onto Centre Line

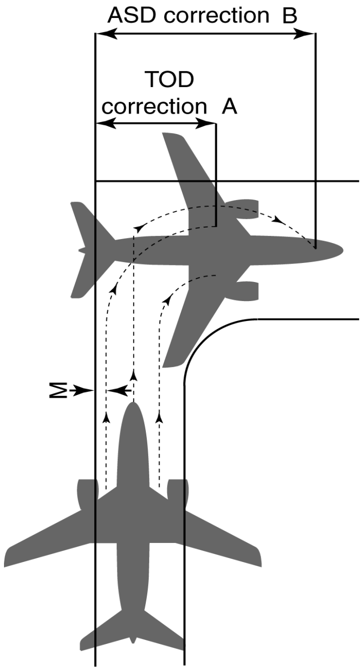


FIGURE 5-6

Aerodrome Surface Dimensions

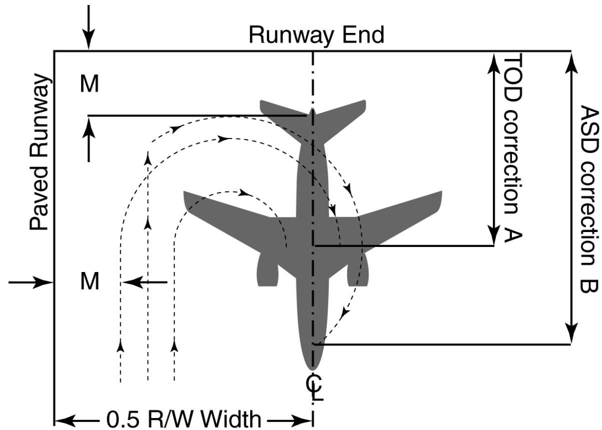
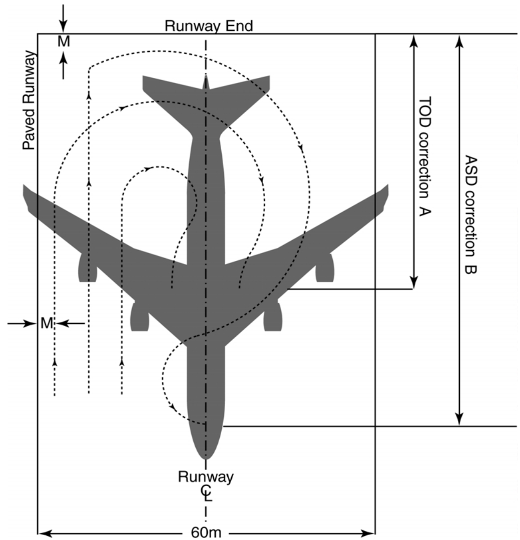


FIGURE 5-7



Balanced Field Lengths

20. A balanced field exists when the length of clearway is equal to the length of stopway. It is described in CAP 168 Chapter 3 Appendix 3C paragraph 2.1.3 as the occasion when TODA equals ASDA (EMDA). There are two circumstances which are considered balanced which are depicted at Figure 5-8.

(a) Clearway equal to stopway length

(b) No clearway nor stopway.

21. There are, therefore, three circumstances which are unbalanced and are shown at Figure 5-9. They are:

(a) Stopway > Clearway

(b) Clearway available but no Stopway.

(c) Clearway > Stopway.

22. The purpose of using balanced field lengths is that the process of calculating the field-length limited TOW for some aircraft can be simplified. However to use a balanced field calculation method when the distances available are unbalanced means that the maximum TOW will not be calculated or used because some distance will be wasted.

Aerodrome Surface Dimensions

FIGURE 5-8
Balanced Field Lengths

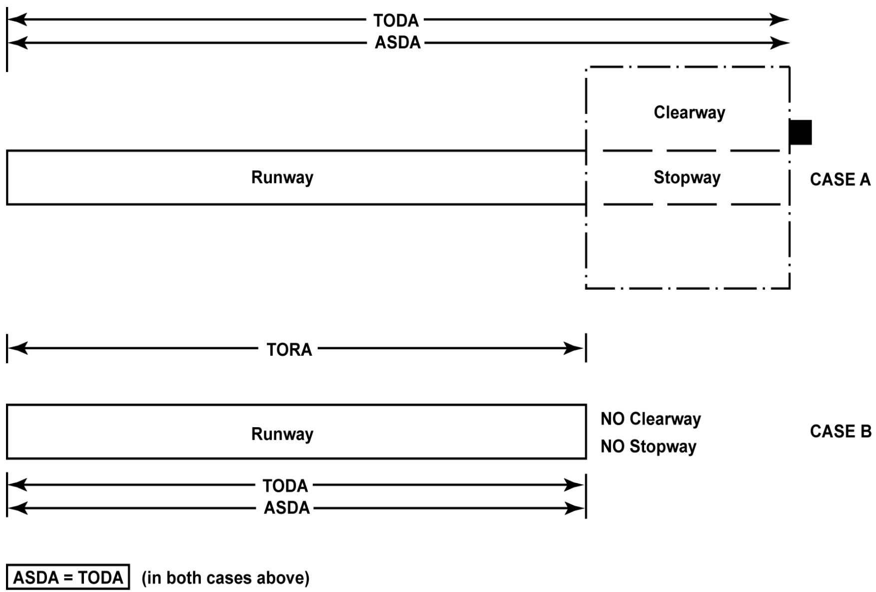
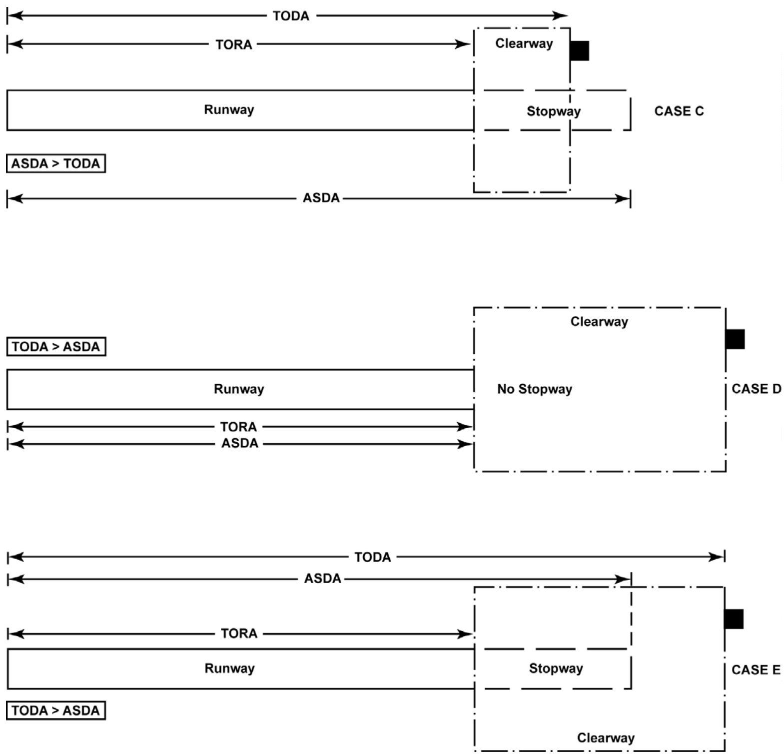


FIGURE 5-9
Unbalanced Field Lengths



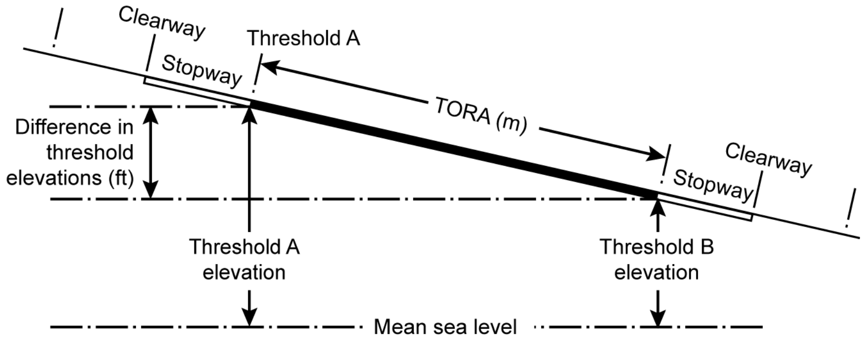
Runway Slope

23. In most cases the published aeroplane performance data gives take-off and landing distance assuming a level runway. In the case of a sloping runway the effect of gravity will be to shorten the take-off run required (TORR) and the take-off distance required (TODR) when the slope is downhill. An uphill slope will provide the opposite effect, increasing TORR and TODR.

24. In the case of landing a downhill sloping runway will extend the landing distance required (LDR), whereas an uphill slope will decrease it. Consequently, it may be necessary to reduce the aircraft weight for an uphill take-off or a downhill landing. It should also be borne in mind that, as with the landing case, an abandoned take-off will require a greater stopping distance on a down-sloping runway.

25. Runway slope is expressed as a percentage uphill or downhill and is calculated using the elevations above mean sea level at either end of the take-off run available (TORA), as illustrated at Figure 5-10. These values may be obtained from the AGA section of the UK Aeronautical Information Publication (UK AIP) – The Air Pilot.

FIGURE 5-10
Runway Slope



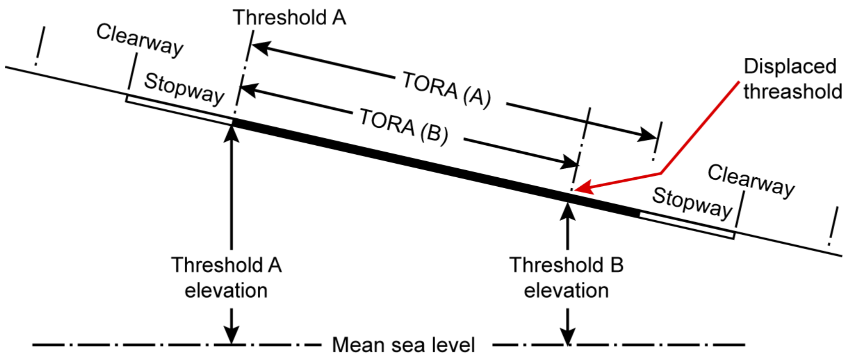
The Calculation of Runway Slope

26. It is usual for the threshold elevations to be given in feet above mean sea level. However, the field lengths may well be quoted in metres, in which case it is necessary to convert the TORA to feet by multiplying by 3.28. Runway slope is always a gradient quoted as a percentage. It can be calculated by using the formula:

$$\frac{\text{Difference in threshold elevations}}{\text{TORA x 3.28}} \times 100 = \%$$

27. If the TORA's in opposite directions are of different lengths then one threshold is displaced and the shorter TORA must be used in the formula. The longer TORA cannot be used because that would infer that part of the stopway of the opposing runway is being used for take-off which is not permitted. This is illustrated at Figure 5-11.

FIGURE 5-11
Runway Slope Calculation



EXAMPLE 5-1

EXAMPLE

Given:
R/W 27, TORA 1000m, EMDA 1200m, TODA 1500m,Threshold elevation 240 ft.

R/W 09, TORA 1000m, EMDA 1100m, TODA 1200m,Threshold elevation 200 ft.

Determine the runway slope for R/W 27.

SOLUTION

$$\frac{(240 - 200)}{1000 \times 3.28} \times 100 = 1.2\% \text{ down}$$

EXAMPLE 5-2

EXAMPLE

Given:
R/W 36, TORA 900m, EMDA 1100m, TODA 1000m, Threshold elevation 175 ft.

R/W 18, TORA 1100m, EMDA 1200m, TODA 1300m, Threshold elevation 210 ft.

Determine the runway slope for R/W 18.

SOLUTION

$$\frac{(210 - 175)}{900 \times 3.28} \times 100 = 1.2\% \text{ down}$$

Obstructions

28. Obstacles, such as trees, tall buildings, high ground, power cables etc. in the approach or take-off flight path will affect the landing distance availability (LDA) or take-off distance available (TODA). Data concerning obstructions in the vicinity of aerodromes is contained in the AGA section of the UK AIP. For information regarding obstructions beyond the limited scope of the AIP, reference should be made to ICAO Type A charts and large scale maps. This is particularly important when considering the take-off flight path, since the scope of the AIP data in respect of obstructions is usually not more than 4 nautical miles from the centre of the aerodrome, or the aerodrome reference point. ICAO Type A charts provide obstacle data to a surveyed distance of 8.1 nm (15000m) from the end of the runway or clearway, unless no obstacles are present up to that range.

Runway Surface

29. Performance data from which take-off and landing distance required is calculated is usually based upon a hard, dry runway surface. Other surfaces, such as grass, will retard acceleration and therefore increase the take-off run. Thus the measured performance data must be factored to allow for the retardation effect of surfaces other than, typically hard dry concrete. These safety correction factors are usually published as notes or addenda to the performance data.

Meteorological Data

30. There are a number of meteorological conditions which will have a significant effect upon an aeroplane's performance. Air density, which directly affects both aeroplane and engine performance, is dependent upon pressure altitude and ambient air temperature (density altitude). The wind speed and direction will determine the wind component (headwind, tailwind, crosswind) which will affect the length of the take-off and landing run. The state of the runway (dry, wet, snow or covered) will also affect take-off and landing performance.

Pressure Altitude

31. For all performance calculations the pressure altitude is used i.e. the altitude indicated on an altimeter that has 1013.2 hPa set on the sub-scale. The pressure altitude of an aerodrome is therefore the vertical distance in feet of that aerodrome above or below the 1013.2 hPa pressure level. Thus the pressure altitude of an aerodrome changes as the ambient atmospheric pressure changes. Only major aerodromes broadcast or have readily available the aerodrome pressure altitude. If it is not available then the pilot must calculate it so that the performance calculations can be completed.

Calculation of Pressure Altitude

32. Aerodrome elevation is normally given in feet above mean sea level (amsl)*. Using a decrease of 1 hPa per 30 ft gain in height, and given QNH, aerodrome pressure altitude can be calculated using the formula:

$$\text{Pressure altitude} = \text{Elevation} + [30 \times (1013 - \text{QNH})]$$

NOTE:

*The AGA section of the UK AIP includes aerodrome elevation in the Aerodrome Directory.

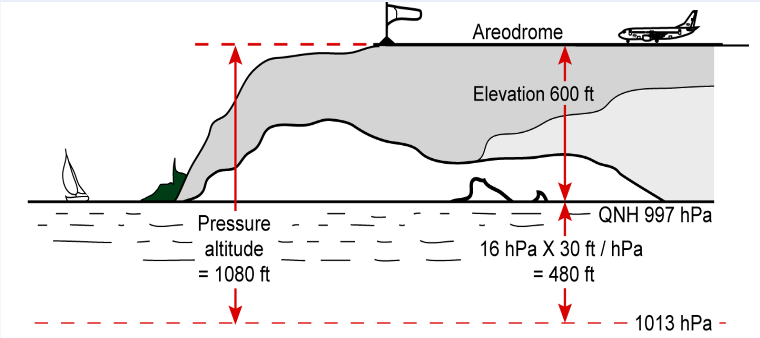
Aerodrome Surface Dimensions

EXAMPLE

Given an aerodrome elevation of 600 ft and a QNH of 997 hPa, determine the aerodrome pressure altitude.

SOLUTION

Pressure Altitude	=	600 + [30 x (1013 - 997)]
	=	600 + (30 x 16)
	=	600 + 480
	=	1080 ft



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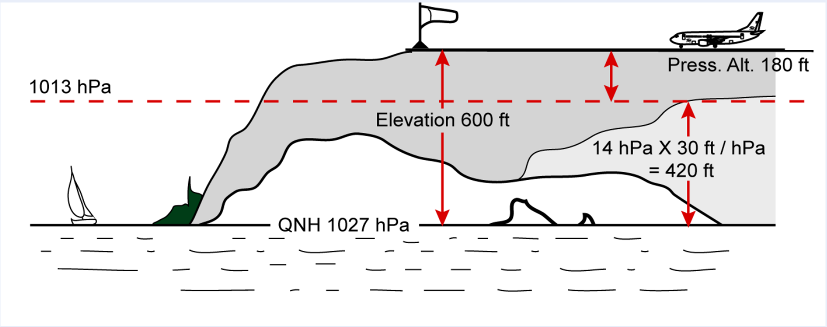
EXAMPLE

Given an aerodrome elevation of 600 ft and a QNH of 1027 hPa, determine the aerodrome pressure altitude.

SOLUTION



Pressure Altitude	=	600 + [30 x (1013 - 1027)]
	=	600 + (30 x -14)
	=	600 + (-420) = 180ft

If QFE (the atmospheric pressure at the aerodrome elevation) is known, the formula for calculating aerodrome pressure altitude is simply:

Pressure Altitude	=	30 x (1013 - QFE)

EXAMPLE 5-5

EXAMPLE

Given QFE of 998 hPa, determine the aerodrome pressure altitude.

SOLUTION

Pressure Altitude	=	30 x (1013 - 998)
	=	30 x 15
	=	450 ft

Density Altitude

33. Calculation of density altitude is not normally necessary, since performance data usually includes corrections for temperature deviation from ISA as well as for various pressure altitudes. The navigation computer has a facility for calculating density altitude if required. Density altitude is defined in Chapter 6.

Temperature

34. The regulations require that performance must be assessed using the **actual** or **reported** temperature for **take-off**. For **en-route or landing** performance calculations the **expected** or **forecast** temperatures must be used. Ambient temperature (the free air static temperature) is normally given in degrees Celsius (°C). Performance data variations with temperature are usually given as temperature deviation from ISA (in °C).

35. ISA mean sea level temperature is +15°C and temperature decreases at the rate of approximately 2°C per 1000 ft of altitude gain. Thus, at a pressure altitude of 3000 ft the standard temperature is:

$$(+15°) - (3 \times 2°C) = +15 - 6 = +9°C$$

36. If the ambient temperature at 3000 ft is actually +12°C, the temperature deviation from ISA is +3°C.

37. When determining a temperature deviation from the standard atmosphere, or when determining the ambient temperature deviation, remember that:

$$\text{Deviation} = \text{Ambient} - \text{Standard}$$

Wind

38. As mentioned earlier, windspeed and direction is of great importance when considering aeroplane performance during take-off and landing. The regulations require that, for **take-off** performance assessment the **reported** or **actual** wind must be used. For **en-route and landing** performance assessment the **expected** or **forecast** winds must be used. Wind directions given in meteorological information are usually relative to true north, whereas Air Traffic Control reported winds are usually relative to magnetic north. It should be borne in mind that runway directions are related to magnetic north.

39. The regulations concerning calculations of take-off and landing distances require that not more than 50% of a headwind component and not less than 150% of a tailwind component is used. This factoring is to allow for variations in windspeed and direction, vagaries of forecasting and variations between wind measurement locations. This factorisation may be built into the flight manual performance data, but in the case of most light aircraft it is not.

Runway State

40. The condition or state of the runway surfaces at the departure and destination airfields is added to the half-hourly Meteorological Aerodrome Report (METAR) when conditions are abnormal. The adverse effect of standing water, slush or snow on rates of acceleration (take-off) and braking (landing or aborted take-off) are important factors in the performance assessment.

Miscellaneous Definitions

Miscellaneous Definitions

Height, Altitude and Elevation

Height. The vertical distance between the lowest part of the aircraft and a relevant datum, in an unbanked attitude with the undercarriage extended.

Gross Height. The true height at any point on the gross take-off flight path. It is converted to pressure altitude in order to determine the indicated height of flap retraction and at which obstacles in the take-off flight path will be cleared. It is also used to denote the height at which speed/power changes must be made.

Net Height. The true height of any point on the net take-off flight path. It is used to plot the take-off flight path so as to ensure that the minimum legal clearance of all obstacles in the aircraft's path is attained.

Screen Height. The height of an imaginary screen which an aircraft would just clear in an unbanked attitude, with the undercarriage extended. For take-off it is located at the end of the take-off distance required (TODR) and for landing at the beginning of the landing distance required (LDR).

Maximum Relight Altitude. Sometimes referred to as re-start altitude. The altitude up to which it has been demonstrated to safely and reliably, re-start an engine in flight.

Altitude. The vertical distance between the lowest part of an aircraft and a specified pressure surface datum. The pressure difference is converted to feet using the International Standard Atmosphere.

Pressure Altitude. The altitude of an aircraft above the pressure level of 1013.2 mb. It can be ascertained by setting the altimeter sub-scale to 1013.2 mb and reading the indicated altitude.

Density Altitude. The altitude in the standard atmosphere at which the prevailing density would be found.

Stabilising Altitude. The maximum altitude at which a multi-engined aeroplane can maintain level flight (0% gradient) with one (or more) engine inoperative.

Elevation. The vertical distance of a fixed point measured above mean sea level (AMSL).

Airfield Elevation. The elevation of the highest usable point of the landing area of a given airfield.

Reference Data

Ordnance Datum. A horizontal plane passing through a point on the surface of a particular runway at the centre of the end of TODA. It is sometimes used to calculate the height of all obstacles, for promulgation by the airfield operator.

Reference Zero (RZ). An imaginary plane passing through a point vertically beneath the aircraft at the end of the TODR. It is used as the plane to which positions on the take-off flight path are sometimes related.

Brakes Release Point (BRP). The position at which the take-off roll begins, sometimes used as an alternative reference point for positions on the flight path for British constructed aeroplanes.

Altimeter Settings

QFE. The atmospheric pressure at the elevation of an aerodrome or runway threshold which, when set on the altimeter sub-scale, will cause the altimeter to read zero.

QNE. The indicated height on landing when the altimeter sub-scale is set to 1013.2 mb, in other words the pressure altitude of the runway.

QNH. The setting on the sub-scale of an altimeter which will cause the instrument to indicate the height of the aircraft above MSL, when the aircraft is on the ground. It is normally set by civilian aeroplanes operating in the vicinity of an aerodrome.

Standard Pressure Setting. An altimeter sub-scale setting of 1013.2 mb.

Flight Level. A surface of constant pressure which is related to the standard atmosphere pressure level of 1013.2 mb. It is referred to in terms of the pressure altitude divided by 100. Thus, FL300 equates to a pressure altitude 30,000 ft.

Weight

All-Up Weight (AUW). The total weight of an aircraft, including fuel, crew and payload, at any specific time. It is a non-standard term often used by companies.

Design Minimum Weight. The lowest aeroplane weight for which compliance has been shown with structural requirements.

Miscellaneous Definitions

Basic Weight. Basic weight is the weight of the aircraft and all its basic equipment, plus that of the declared quantity of unusable fuel and unusable oil. In the case of turbine-engined aircraft the Maximum Total Weight Authorised of which does not exceed 5700 kg, it may also include the weight of usable oil.

Design Maximum Weight. The greatest of the following weights at which an aeroplane complies with the structural requirements:

(a) Design Take-Off Weight – the greatest aeroplane weight at which compliance is shown with the structural requirements for taxiing or landing at a reduced velocity of descent.

(b) Design En-Route Weight – the greatest aeroplane weight at which compliance is shown with the structural requirements for flight conditions other than those associated only with take-off or landing.

(c) Design Landing Weight – the greatest aeroplane weight at which compliance is shown with the structural requirements for landing at the maximum velocity of descent.

Empty Weight. The weight empty is precisely defined for each particular aeroplane. For practical purposes it excludes crew and payload, but includes fixed ballast, unusable fuel, undrainable oil, total quantity of engine coolant and total quantity of hydraulic fluid.

Take-Off Weight (TOW). The weight of the aircraft at the commencement of the take-off or of the take-off run shall be taken to be its gross weight including everything and everyone carried in or on it at the commencement of the take-off run or of the take-off.

Maximum Take-Off Weight. The maximum weight at which take-off is permitted by considerations other than available performance.

Maximum Weight. The greatest of the two following weights:

(a) Maximum Take-off Weight. The maximum weight at which take-off is permitted, by conditions other than available performance.

(b) Maximum Landing Weight. The maximum weight at which landing (other than in an emergency) is permitted by considerations other than available performance.

WAT Limit Weight. Weight, Altitude and Temperature Limit Weight. The highest weight at which all relevant climb minima can be achieved.

Maximum Zero Fuel Weight (**Max ZFW**). The aeroplane weight above which all weight must be in fuel or load in the wing.

Atmospheric Conditions

Atmosphere, International Standard. The atmosphere defined in ICAO Document 7488/2. For the purposes of **JAR** the following is acceptable:

(a) The air is a perfect dry gas.

(b) The temperature at sea leavel is 15°C.

(c) The pressure at sea level is 1.013250 x 10^5 Pa (29.92 in Hg) (1013,2 mb).

(d) The temperature gradient from sea level to the altitude at which the temperature becomes –56.5°C is 3.25°C per 500m (1.980C/1000 ft).

(e) The density at sea level Pa, under the above conditions is 1.2250 kg/m^3 (0.002378 slugs/ft^3).

NOTE:

P is the density appropriate to the altitude and P/P_0 the relative density is indicated by 0.

Relative Humidity. The moisture content of the free air, excluding free water. It is usually expressed as a percentage of total saturation.

Declared Temperature. The average temperature for the month under consideration, plus half the associated standard deviation.

Indicated Temperature (IAT or TAT). The static air temperature plus the heating rise caused by adiabatic compression, as indicated on the Total Air Temperature indicator.

Maximum Temperature. In relation to aeroplane performance, the highest temperature at which all performance requirements can be fulfilled at any given altitude.

Minimum Temperature. In relation to aeroplane performance, the lowest temperature at which all performance requirements can be fulfilled at any given altitude.

Aerodrome Obstacles

Frangibility. The ability of an object to retain its structural integrity and stiffness up to a specified maximum load.

Frangible Obstacle. An object which, when struck by a force imposing on it a load greater than a specified maximum, will distort, yield or break into pieces in such a way that it presents only minimum hazard to aircraft on the ground or in the air.

Obstacle. Any object which endangers the movement of aircraft on the ground or, if the object extends above a defined surface level, in the air. It can be a mobile or a fixed object, and of either a permanent or temporary nature.

Surfaces and Areas

Balked Landing. An inclined plane commencing at a specified distance after the Surface threshold (at the elevation) of the runway, and extending between the inner transitional surfaces of the aerodrome area.

Gradient (or Slope). The ratio of a change in height to horizontal distance travelled, expressed as a percentage. It is called the slope when aerodrome surfaces are being described and gradient when referring to the take-off flight path.

Runway Strip. An area of defined dimensions which includes the runway and the stopway, if present. Its purpose is to reduce the risk of damage to aeroplanes taking-off from, landing on or over-running the runway.

Take-Off. For performance purposes, a plane of infinite extent and uniform Landing Surface slope extending in the direction of take-off and landing.

Take-Off Climb. A specified surface area or inclined plane extending beyond the Surface end of the runway or clearway in the direction of take-off.

Aeroplane Power Unit(s)

Bleed Air. Air taken from the main compressor of an engine to be used for cabin pressurisation and/or other ancillary services.

Critical Power Unit. The power unit or units which, if it or they failed completely, have the most adverse effect on the performance characteristics of an aeroplane.

Engine Pressure Ratio (EPR). One of the parameters used to determine thrust. It is usually the ratio of jet pipe pressure to compressor inlet pressure of a gas turbine engine.

Power Augmentation. Any recognised or accepted method of providing increased power output and improved performance over a short period of time. The term includes the injection of a refrigerant.

Power Unit. A system of one or more engines, with ancillary parts, which can independently provide the required thrust.

Power Unit Failure. The complete and immediate loss of propulsive power from a failed power unit, save for the power momentarily provided by the inertia of moving parts.

Power Unit Failure Point. The point at which, for performance purposes, sudden and complete failure of a power unit is deemed to occur.

Power Unit Relight Altitude. The maximum altitude at which the restart of a failed power unit may be safely and reliably attempted to restart in flight.

Reverse Thrust. A mechanical method of utilising the thrust output of a power unit to help retard an aeroplane after a take-off has been abandoned, or during the landing run on the ground.

Performance

Measured Performance. The average performance of an aeroplane or group of aeroplanes undergoing a test by an acceptable method under specified conditions.

Gross Performance. The measured performance of an aeroplane type adjusted in such a way that any particular aeroplane of that type is at least as likely to exceed the gross performance as not.

Net Performance. The gross performance of an aeroplane type diminished in a manner prescribed by the Airworthiness Requirements to allow for variations in performance not included in the Operational Regulations. Varying pilot techniques would be an example.

Gross Flight Path. The profile path of an aeroplane after it has reached the end of (GFP) the TODR. The GFP is plotted using the gross performance data, and ends at the same horizontal distance **from the point of take-off as does the NFP.** It starts at the screen height and at any specific distance will always be above the NFP.

Net Flight Path. The profile path of an aeroplane from the end of the TODR until (NFP) it reaches 1500 net height above reference zero. It is plotted using the net performance data.

Climb Gradient. The ratio of an aircraft's change in height to the horizontal distance it has travelled, expressed as a percentage.

Significant Turn. The radius of a steady 15° banked turn in still air, at the various true air speeds corresponding to the take- off safety speeds for each wing-flap setting used in determining the take-off net flight path shall be determined and scheduled.

Speeds

Speeds

NOTE:

IT IS ESSENTIAL TO BE THOROUGHLY CONVERSANT WITH THE FOLLOWING DEFINITIONS AND EXPLANATIONS OF TAKE-OFF SPEEDS AND DISTANCES

Definitions

IAS. Indicated airspeed is the speed of an aircraft as shown by it pitot/static airspeed indicator calibrated to reflect standard atmosphere adiabatic compressible flow at MSL and corrected for instrument error.

CAS. Calibrated airspeed is the indicated airspeed corrected for position error. Also know as Rectified Airspeed (RAS).

EAS. Equivalent airspeed is the calibrated airspeed corrected for 'adiabatic compressible flow'.

TAS. True airspeed is the equivalent airspeed corrected for density error and is the true speed of the aircraft relative to the undisturbed air.

G/S. Groundspeed is the rate at which the aircraft travels over the ground and is equal to TAS ± the along track wind component.

Stalling Speeds

VS. Stalling Speeds is the greater of:

(a) The minimum CAS when the aeroplane is stalled (or the minimum steady flight speed at which the aeroplane is controllable with the longitudinal control on its stop)

(b) A CAS equal to 94% of the one – g stall speed, VS1G. *[JAR-25.103 (b)]*.

VS1G. The one-g stall speed is the minimum CAS at which the aeroplane can develop lift equal to its weight at an angle of attack not greater than that at which the stall is identified. *[JAR-25.103 (c)]*.

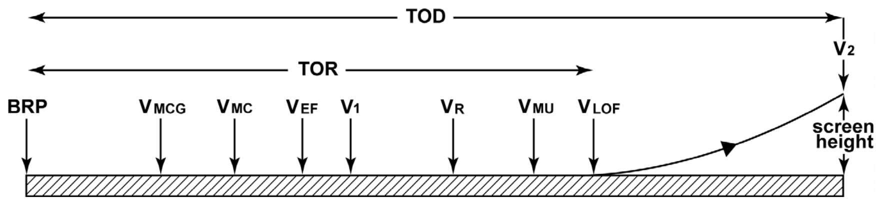
VMS1. The minimum speed in the stall (or if no stalling is obtainable, the minimum steady – flight speed) with the aeroplane in the configuration appropriate to the case under consideration (CAS).

VS1. The stalling speed (or if no stalling speed is obtainable, the minimum steady-flight speed) with the aeroplane in the configuration appropriate to the case under consideration (CAS).

VSO. The stalling speed (or if no stalling speed is obtainable, the minimum steady-flight speed) with the wing flaps in the landing setting (CAS).

Take-Off Speeds and Required Distances

FIGURE 7-1
Take Off Speeds & Distances



VMCG. The minimum control speed on the ground, CAS, at which if the critical power unit suddenly fails it is possible to maintain control of the aeroplane with the use of primary aerodynamic controls alone (without the use of nosewheel steering) to enable take-off to be safely continued using normal piloting skill only using lateral control to keep the wings level. The point at which the critical power unit to the point at which recovery to a direction parallel to the centre line is not to be more than 30 ft laterally from the centre-line at any point. VMCG may not exceed VMC. *[JAR-25.149 (e)]*. An increase of aerodrome pressure altitude and/or ambient temperature decreases VMCG.

VMC. Is the calibrated airspeed at which, when the critical engine is suddenly made inoperative, it is possible to maintain control and maintain straight flight using no more than 5° of bank without required exceptional piloting skill or the aeroplane adopting a dangerous attitude or changing heading by more than 20°. VMC is always greater than VMCG. *[JAR-25.149 (b)]*. An increase of aerodrome pressure altitude and/or ambient temperature decreases VMC.

VEF. Is the calibrated airspeed at which the critical engine is assumed to fail. It is never less than VMCG or greater than V1. *[JAR-25.107 (1)]*.

V1. In terms of calibrated airspeed, is the take-off decision speed. It is never less than VEF plus the speed gained with the critical engine inoperative during the time interval between the instant at which the critical engine failed, and the instant at which the pilot recognizes and reacts to the engine failure, as indicated by the pilot's application of the first retarding means. This time interval is assumed to be 2 seconds. *[JAR-25.107 (a) (2)]*.

It is the speed determined by the field length, aircraft configuration and all-up weight (AUW) at which, in the event of a power unit failure, the pilot must decide whether to abandon or to continue the take-off; because at this speed that the aircraft can be safely brought to rest on the ground or safely become airborne. Engine failure before this speed demands the abandonment of take-off. Above this speed the aircraft is committed to becoming airborne even if an engine fails.

V1 is never less than VMCG, nor greater than either VR or VMBE

In certain circumstances a range of V1's is possible. If V1 is increased to the maximum permissible it will increase the length of the ground run (TORR) and the distance taken to reach screen height (TODR). If balanced field distances EDA = TODA or ASDA= TODA are used when the field distances are unbalanced then the V1 will be reduced because all of the available distances have not been utilised in its determination.

VGO. The lowest decision speed from which a continued take-off is possible within the take-off distance available. *[AMJ 25X1591 (b). Note]*.

VSTOP. The highest decision speed from which the aeroplane can stop within the accelerate/stop distance available. *[AMJ-25X1591 (b). Note]*.

VR. The speed at which, in both the all engines operating and the one-engine inoperative configurations, the pilot should initiate a change of attitude on the ground run, by raising the nose-wheel and rotating the aircraft about its lateral axis. Its exact value varies with AUW, flap setting, pressure altitude and ambient temperature. It may not be:

(a) Less than V1.

(b) Less than 105% VMC.

(c) Less than the speed required to attain V2 by screen height.

(d) Less than the speed required to ensure VLOF is 110% VMU, with all engines operating, and not less than 105% VMU with one engine inoperative, except that if lift off is limited, by the geometry of the aeroplane or by elevator power the margins are reduced to 108% with all engines operating and 104% with one engine inoperative. *[JAR-25.107 (e)]*.

The value of VR increases with increased aerodrome pressure altitude and/or increased ambient temperature but decreases with increased flap angle up to the maximum permissible for take-off.

VMU. is the calibrated airspeed at and above which the aeroplane can safely lift-off the ground, and continue the take-off. It is the minimum unstick speed, at which aeroplane can leave the ground and climb to screen height without undue hazard. It is the lowest speed for VLOF under any conditions. *[JAR-25.107 (d)]*.

VLOF. is the calibrated airspeed at which the aeroplane first becomes airborne. Often referred to as Lift-off speed. It is the speed at which the main wheels will leave the ground if the aircraft is rotated about its lateral axis at VR. This speed is a direct function of aircraft weight and flap setting, and is sometimes called the unstick speed. *[JAR-25.107 (f)]*.

Take-Off Run Required (TORR). The calculated distance from the commencement of the take-off run to the point at which VLOF is achieved.

VMBE. The maximum brake energy speed is the maximum speed on the ground from which the aeroplane can be brought to a complete stop within the brake energy capabilities of the aeroplane braking system in the prevailing conditions.

The maximum safe operating temperature for large aircraft braking systems is between 450°C and 500°C above which the brakes will fail. Low density will cause a high TAS conversion from CAS and consequently a high groundspeed. In the event of an abandoned take-off in such conditions the limiting temperature may be attained very quickly. This situation will be exacerbated taking off downhill and/or downwind. V1 may not exceed VMBE, if it does then the TOW must be reduced to comply with this requirement.

V2. The take-off safety speed, sometimes called the free air safety speed. It is the minimum speed which the aircraft is legally required to achieve on reaching the screen height with one power unit inoperative. It is the lowest safe climbing speed. The exact speed is determined by the take-off weight and the flap setting. V2 will also vary with aerodrome height AMSL and temperature. V2 decreases with increased ambient temperature and/or aerodrome pressure altitude and/or increased flap setting up to the specified maximum for take-off.

V2MIN. In terms of calibrated airspeed, may not be less than:

(a) 1.2 VS for 2 and 3 engined turbo-props and jet aircraft without provisions for obtaining a significant reduction in the one-engine inoperative stalling speed.

(b) 1.15 VS for 4 engined turbo-prop and jet aircraft with provisions for obtaining a significant reduction in the one-engine-inoperative stalling speed.

(c) 1.1 x VMC.

Screen Height. The height of an imaginary screen which an aircraft would just clear in an unbanked attitude, with undercarriage extended. For take-off it is located at the end of TODR and for landing at the beginning of the LDR. *[BCAR K2-2.7.2.4.].*

Take-off distance required (TODR). Is the calculated distance from the commencement of the take-off run to the point at which the aircraft attains screen height.

V3. The steady initial climb speed, with all engines operating, which must be achieved by the screen height. It is never less than V2 + 10 kt.

V4. The steady take-off climb speed, with all engines operating, using the scheduled techniques and achieved by minimum flap retraction height. It is not less than 1.2 VMC or 1.3 VMS1, and is such that the gross flight path attained does not fall below the gross flight path from which the net flight path is derived. V4 is required in procedures for the abatement of noise.

The Effect of Density on Speed

1. The density of the atmosphere depends on three variable factors – altitude, temperature and humidity. An increase in any one of these factors will decrease the density, a combined increase in the factors will result in a greater decrease in density.

2. In the standard atmosphere at mean sea level a 1000 ft. increase in altitude will decrease the density by 3%. However, the same increase of altitude normally results in a 2°C decrease in temperature. This causes an increase of density by 0.66%. Thus the increase in altitude has the greater effect and the overall reduction in density is 2.34%.

3. Take-off speeds are determined by AUW, flap setting and density. Generally the speeds increase with increase of weight but decrease with increased flap setting. However, density has a direct effect on the speeds because the loss of the critical engine power on take-off causes a yaw which must be counteracted by the rudder.

4. The power developed by the engines is directly proportional to the density. Therefore, in a dense atmosphere. The loss of power from one engine causes a greater yaw than in a less dense atmosphere. Thus in a dense atmosphere, the rudder authority required to counteract the yaw can only be obtained at a higher speed. Hence the minimum control speeds V_{MCG}, V_{MC}, and free air safety speed (V_2) increase with increased density. Rotation speed (V_R) decreases with increased density, because the greater amount of thrust and lift generated enables the aeroplane to reach flying speed earlier. See Figure 7-2.

5. The next important effect density has with relationship to take-off speeds is that of the conversion of the calculated CAS to TAS. A decrease of air temperature decreases the TAS whereas an increase of altitude increases the TAS i.e. high altitude and high temperature increase TAS. This results in a higher groundspeed. Therefore at high aerodromes for a given AUW and flap setting the V_R is increased which causes a high TAS and a high groundspeed resulting in a longer take-off run.

FIGURE 7-2
Example Take-Off Speeds

CONDITIONS		TAKE-OFF SPEEDS – KTS					
AIRFIELD PRESSURE ATITUDE	AMB TEMP °C	CAS VMCG	CAS VMC	CAS VR	TAS VR	CAS V2	TAS V2
MSL	+ 35°C	112	114	142	147	152	157
MSL	+ 45°C	108	109	144	151	150	158
5000 ft	+ 35°C	102	104	145	164	149	168

NOTE:

Increased temperature and/or altitude decreases VMCG, VMC and V2 but increases VR and TAS. Therefore the calculated distance from brake release point (BRP) to the point at which the wheels leave the ground (TORR) and to reaching screen height (TODR) are both increased.

6. With some smaller aeroplanes the take-off speeds are so low that the manufactures consider the effect of altitude and temperature to be insignificant and only show speed changes against AUW and flap setting.

FIGURE 7-3
Effect of Flap on Speeds

SPEED KTS	30° FLAP		18° FLAP	
AUW	V_R	V_2	V_R	V_2
11500 lbs	59 kts	65 kts	70 kts	74 kts
12500 lbs	63kts	69 kts	76 kts	81 kts

7. Figure 7-3 illustrates that a high flap setting considerably reduces the V_R and V_2 speeds. Further investigation would also show a large decrease in the TORR and TODR.

8. Additional advantages of keeping the V_R as low as possible, by using a high angle flap setting and taking off when the temperature is low, are that the TAS and groundspeed will be minimized thus reducing the likelihood of exceeding the maximum speed limit of the tyres or the maximum operating temperature of the braking system, in the event of an abandoned take-off.

Approach and Landing Speeds

V_{AT} Target threshold speed is the speed at which the pilot aims to cross the threshold at the screen height when landing. It is an average speed calculated for conditions of light winds and slight turbulence, and is determined by the aircraft weight and flap setting. It may be specified either for the all-power-units-operating condition (V_{AT0}), for the one-power-unit-inoperative (V_{AT1}) condition, or for the two-power-unit-inoperative (V_{AT2}) condition.

V_{AT0}. The target threshold speed for an all-power-units operating approach which is not less 1.3 V_{S0} following a steady descent to screen height of not greater than 5%.

VAT1. The target threshold speed for a one-power-unit inoperative approach, which is not less than VAT0.

VREF. The reference landing speed is that attained at screen height in a specified configuration in the determination of the landing distance for manual landings.

VT. The threshold speed

VTMAX. The maximum threshold speed.

Miscellaneous Speeds

VIMD. The velocity of minimum drag is the speed achieved at the lowest point of the total drag curve.

VIMP. The velocity of minimum power is the speed attained at the lowest point on the power curve.

VX. The speed used to attain the maximum angle or gradient of climb.

VY. The speed used to attain the maximum rate of climb, normally it is approximately 10 kt above VX.

The Effect of Variables

The Effect of Variables

1. Good airmanship requires a thorough knowledge of the effect that all conditions have on the safe operation of an aeroplane. There are two Aeronautical Information Circulars (AICs) that are specifically directed at the safety aspects of operating small aeroplanes. They are AIC 12/1996 (Pink 120) and AIC 61/1999 (Pink 195). All AICs are replaced approximately every five years. These AICs should be studied in detail.

2. AIC 12/1996 (Pink 120) is concerned with take-off, climb and landing performance of light aeroplanes. It details the publications which contain aeroplane performance data and how that data is to be used. The AIC then goes on to list the variables and guide line safety factors to be considered when assessing take-off, climb and landing performance of light aeroplanes when no specific factorisation is given in the aircraft flight manual or pilot's operating handbook. Factors given in the AFM/POH are the minimum acceptable and are mandatory for all public transport flights. The limitations quoted in these publications and the Certificate of Airworthiness are mandatory for all flights. A summary of this AIC is at the end of this Chapter.

3. AIC 61/1999 (Pink 195) deals with the risks and factors associated with operations on runways contaminated with snow, slush or water. It summarises the assessment of runway surface contamination and the effects of various types and depths of contaminant. It lists the limitations for take-off from contaminated runways and discusses the effect upon take-off performance for aircraft in the various performance groups. The AIC also summarises the risks associated with attempts to land on contaminated runways. A summary of this AIC is at the end of Chapter 4.

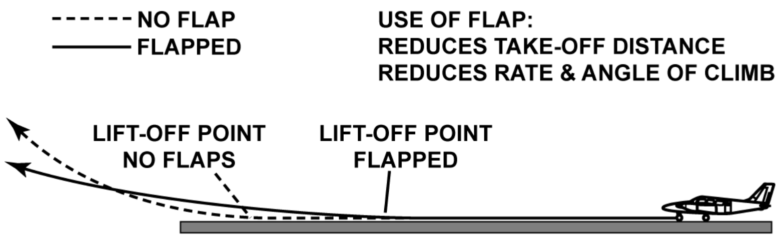
General Effects of Variables

4. Before going on to consider performance assessment of a particular specimen aeroplane it is worth considering the effects of certain variables on take-off and landing performance of aeroplanes.

Effect of Flap Setting

5. Whilst increasing lift, flaps also increase drag. For this reason the use of flap for take-off is limited to small flap settings, if used at all. Using small flap settings for take-off reduces the stalling speed and therefore reduces the lift-off (unstick) speed and consequently reduces the length of the take-off ground run. However, the extra drag of even a small flap setting reduces the lift/drag ratio of the aircraft and therefore reduces both the rate of climb and the angle of climb (climb gradient). This is illustrated at Figure 8-1

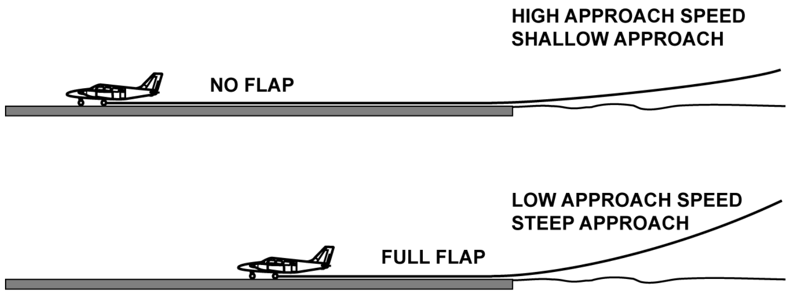
FIGURE 8-1
The Effect of Flap on Take-Off



6. Thus, although the take-off run required (TORR) may be reduced with limited use of flap, the take-off distance required (TODR)(to screen height) may not be reduced significantly. Use of a larger flap setting, even though it might reduce stalling speed further, would increase drag to a point where climb-out performance would be unacceptably poor.

7. For landing the increased drag and reduced stalling speed of large flap settings permits a reduced approach speed and a steeper approach path. Since both of these are desirable during the approach and landing phase higher flap settings are used for landing. This is illustrated at Figure 8-2.

FIGURE 8-2
The Effect of Flap on Landing

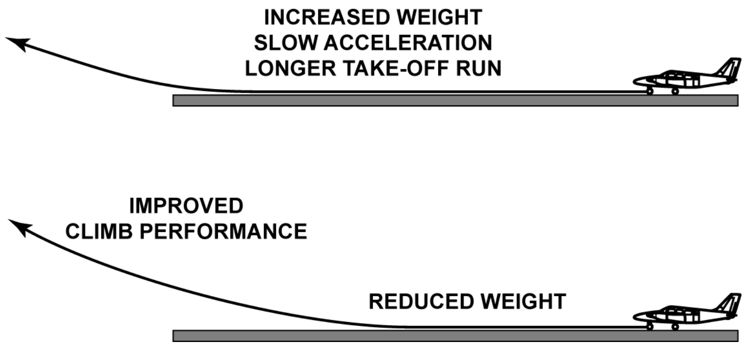


Effect of Aircraft Weight

8. Increased aircraft weight means an increase in take-off distance required, for a number of reasons. The greater mass of the aeroplane means that acceleration is slower. Since Force = Mass x Acceleration, the force of take-off power is unchanged, so if mass is increased acceleration is decreased. Furthermore, the increased weight on the aircraft wheels increases friction, which resists acceleration. Hence, the take-off run required will be longer.

9. Since, for flight, weight must be opposed by lift so increased weight requires increased lift which, in turn, requires increased airspeed. The higher the aircraft weight the higher the stalling speed and, therefore, the higher the lift off speed - again increasing take-off run required. After lift-off, increased weight will mean a reduced rate of climb and climb gradient. Consequently, the distance required to reach screen height will be greater, in other words, take-off distance required is increased. This is illustrated at Figure 8-3.

FIGURE 8-3
The Effect of Weight on Take-Off



10. Similarly, for landing increased weight means a greater landing distance required (LDR). This is because the higher stalling speed will require a higher approach speed. Also, the extra weight will demand more energy absorption by the brakes so the aircraft will travel further during the landing roll. Broadly speaking, a 10% increase in weight requires a 10% increase in landing distance, whereas the take-off distance is increased by approximately 20% for a 10% weight increase.

Effect of Wind Component

11. That element of wind velocity acting parallel to the aircraft direction of travel is known as the along track wind component. The wind component **opposite** to the direction of travel is known as the headwind component (HWC), the component **in the same direction** as the direction of travel is known as the tailwind component (TWC).

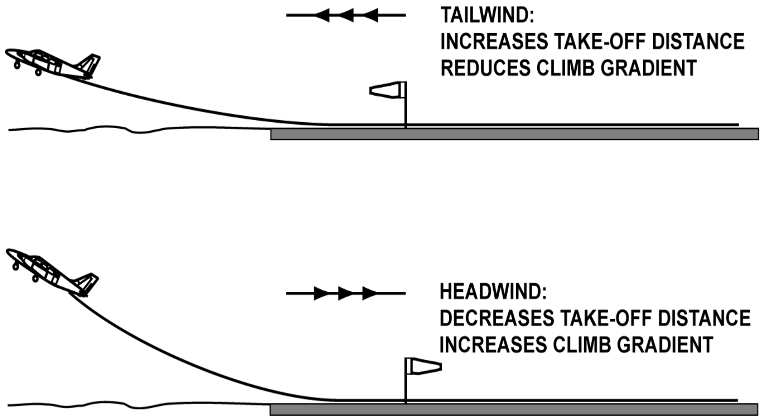
A headwind component reduces the take-off distance required. For flight the aircraft needs to reach lift-off airspeed. Suppose there is a 20 kt HWC, then even before the aircraft begins its take-off run the relative airspeed is 20 kt. The distance it has to travel before it reaches lift-off speed is less than in a still air situation because the groundspeed at lift-off airspeed is lower. Furthermore, once airborne the climb gradient is greater with a headwind. This is because the aircraft has the same rate of climb, but a lower groundspeed, than in still air.

A tailwind component has exactly the reverse effect on take-off distance required. With, for example, a 10 kt TWC the aircraft must accelerate to a groundspeed of 20 kt to produce a headwind of 10 kt. Hence, the distance to lift-off airspeed will be greater than in still air. After lift-off the groundspeed will be higher than the still air case, but rate of climb will be the same. Consequently, the climb gradient will be reduced. The effects of headwind and tailwind on take-off performance are illustrated at Figure 8-4.

Similarly, a headwind component will reduce the landing distance and a tailwind component will increase it. This is because, with a headwind, groundspeed is less than true airspeed, whereas with a tailwind groundspeed is greater than true airspeed.

12. The component of wind velocity acting at right angles to the aircraft direction of travel is known as the crosswind component. Crosswind affects directional (yaw) and lateral (roll) control of the aircraft and for this reason there are published crosswind component limits for take-off and landing.

FIGURE 8-4
The Effect of Wind Component on Take-Off



Effect of Runway Surface

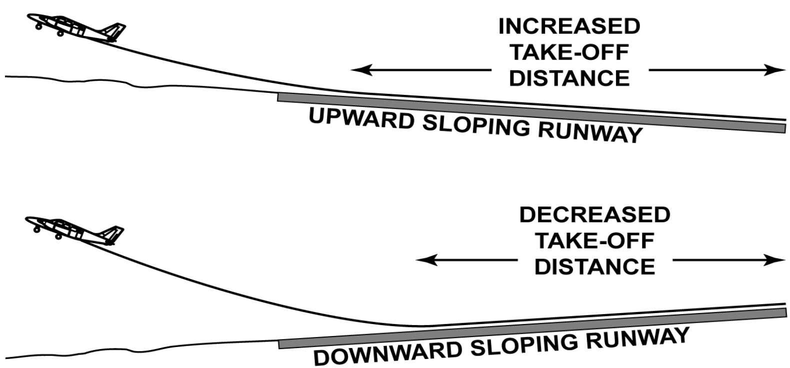
13. Performance data is based on a hard, level and dry runway surface. Other surfaces, such as grass, will retard acceleration and therefore increase the take-off distance by increasing the take-off run required. The rolling resistance is increased if the grass is wet and the longer the grass the greater its resistance. This is made abundantly clear in the text of AIC 12/1996 (Pink 120).

14. Landing distance required is also greater on a grass runway, because of the greater tendency for the wheels to lock and skid during braking.

Effect of Runway Slope

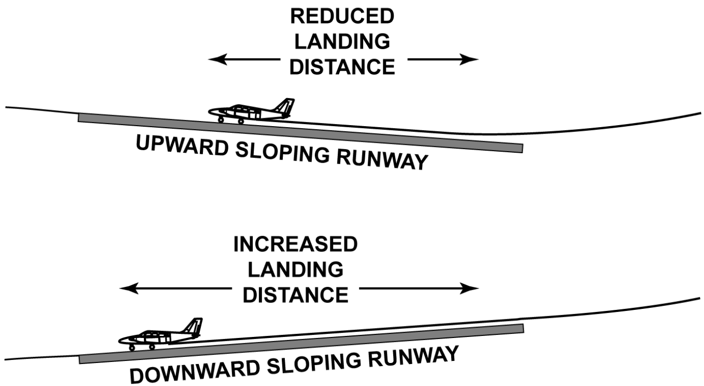
15. This has been discussed previously, but to summarise, a downward sloping runway will permit faster acceleration to lift-off speed and therefore a reduced take-off distance. An upward sloping runway will have the opposite effect. This is illustrated at Figure 8-5.

FIGURE 8-5
The Effect of Runway Slope on Take-Off



16. For landing, a downward sloping runway will increase the landing distance required, because the brakes have to absorb energy due to a component of gravity as well as the kinetic energy of the aeroplane. An upward sloping runway reduces the landing distance required. This is illustrated at Figure 8-6.

FIGURE 8-6
The Effect of Runway Slope on Landing



The Effect of Density

17. The density of the atmosphere depends on three elements, they are altitude, temperature and humidity. An increase in altitude, temperature or humidity will cause a decrease in density, and a combined increase of these elements an even greater decrease in density.

18. Unless there is a temperature inversion an increase in altitude will result in a decrease in temperature. Thus the density is decreased because of the increased altitude but increased because of the decreased temperature.

19. For a 1,000 ft increase in altitude, the decrease in pressure has a greater effect than the decrease in temperature on aircraft performance.

The Effect on Engine Performance. The power/thrust generated by an engine depends on the density of the air. Its volumetric efficiency increases in a dense atmosphere and therefore generates more power. If the power generated is too great the engine could be damaged because the temperature of the exhaust gases may exceed the maximum permitted temperature. In which case the throttle/thrust lever setting must be restricted to a position at which the temperature limitation is not exceeded. This is sometimes referred to as 'The Flat Rating Cut-off'.

A decrease in ambient density will increase the power output. Therefore at high altitudes and high temperatures the aeroplane will be slow to accelerate on the take-off run. This may cause the FLL TOW to be restricted because more of the field-lengths available will be used. Both the TORR and the TODR will be greater because of the poor acceleration.

Similarly, after take-off in the initial climb, because there is a minimum acceptable climb gradient, with a low power output the TOW may have to be restricted to ensure the minimum gradient requirements is attained. This is called the WAT limited TOW or 'Climb-Limited TOW'.

Thus low density causes an increased take-off run or limits the FLL TOW, and a low climb out gradient or limit the WAT TOW.

The Effect on TAS/Groundspeed. The take-off and landing speeds are either EAS or CAS and are determined by the AUW and flap setting on small aircraft but on large aircraft the density also affects their values. The speeds are increased with increased weight and increased with decreased flap setting. With large aeroplanes decreased density will also cause a small increase in speeds. However the effect the density has on TAS, and consequently groundspeed, is considerable. For example for an RAS/CAS of 120 kts. See Figure 8-7.

FIGURE 8-7
TAS Conversion for 120kts.CAS.

AMBIENT TEMP	+ 15°C	+ 5°C
MSL	120	118
5000 ft	132	129 ½

Hence high altitude with high temperature causes high true airspeed and high groundspeed. Thus the TORR and TODR to attain the EAS/CAS speeds for take-off are both increased. Therefore, low density causes longer take-off distances. The same is true for the climb-out, low density causes a low gradient and a greater distance travelled during the climb.

Combined Effect. At low density the decreased power available increases the TORR, which is at a higher groundspeed. Thus the rotational velocity of the wheels is increased causing the maximum tyre speed to be quickly reached and may limit TOW.

20. The brakes have a maximum safe operating temperature above which their efficiency is impaired. When used a certain amount of cooling is obtained from the air but in conditions of low density this will be negligible. If low atmospheric density is combined with the effects of taking off downhill and/or downwind, in the event of an abandoned take-off, the brake temperatures would be extremely high when full braking is applied because of the high groundspeed. Consequently the maximum safe speed from which the aircraft can be brought to rest is limited by the brake energy absorption capacity. This limiting speed is known as VMBE, which can be quite low in conditions of low density, downhill and downwind. If V1 is greater than VMBE then TOW will have to be restricted to ensure V1 does not exceed VMBE.

Aeronautical Information Circular

AIC 112/1996 (PINK 120)

Take-off, Climb and Landing Performance of Light Aeroplanes

Introduction

21. Accidents, such as failure to get airborne in the distance available, collision with obstacles owing to inadequate climb and over-run on landing, continue to occur fairly frequently to light aeroplanes. Many such accidents have occurred when operating from short strips, often taking-off or landing out of wind, or with sloping ground. Poor surfaces such as wet grass or ice were also frequent contributory factors. What is not generally realised by many pilots is that these are performance accidents and many, if not all, of these accidents could have been avoided if the pilots had been fully aware of the performance limitations of their aeroplanes.

22. The pilot-in-command of any UK registered aeroplane has a legal obligation placed on him by Article 35 of the Air Navigation Order which requires him to check that the aeroplane will have adequate performance for the proposed flight. The purpose of this Circular is to remind pilots of private flights of the actions needed to ensure that the take-off, climb and landing performance will be adequate.

23. Aeroplane performance is subject to many variables including:

(a) Aeroplane weight

(b) Aerodrome altitude

(c) Temperature

(d) Wind

(e) Runway length

(f) Slope

(g) Surface

(h) Flap setting

(i) Humidity

24. The performance data will usually allow adjustment to be made for these variables. On certification, allowances are made to cater for slight variations in individual pilots' handling of a specific technique.

Where to Find the Information

25. Performance figures may be given in a variety of publications and it is important for pilots to know where to find the data needed to predict the performance in the expected flight conditions. The appropriate document is specified in the Certificate of Airworthiness and may be any one of the following:

(a) The UK Flight Manual.

(b) The Owner's Manual or Pilot's Operating Handbook. These documents, which sometimes contain CAA Supplements giving additional performance data which may either supplement or override data in the main document, are the ones applicable to many light aeroplanes.

(c) The Performance Schedule (applicable to a few of the older aeroplanes).

(d) For some imported aeroplanes, an English language flight manual approved by the Airworthiness Authority in the country of origin, but with a UK Supplement containing the performance data approved by the CAA.

Use of Performance Data

26. The majority of modern, light aeroplanes are certified in Performance Group E for the purposes of public transport (now in Class B). The performance information in Manuals and Handbooks for Group E aeroplanes is **unfactored,** this means the data represents the performance achieved by the manufacturer using a new aeroplane in ideal conditions. This level of performance will not be achieved if the flying techniques used by the manufacturer are not followed closely or if the meteorological conditions are not as favourable as those encountered during testing. It is therefore **prudent to add safety factors** to the data in order to take account of less favourable conditions.

27. To ensure a high level of safety on public transport flights, there is a legal requirement to add specified safety factors to the data. It is **recommended** those same factors be used for private flights. When a pilot planning a private flight chooses to accept aerodrome distances or climb performance less than that required for a public transport flight, he should recognise that the level of safety is lowered accordingly.

28. Performance data in Manuals for aeroplanes certificated in Performance Groups B, C, D or F for the purposes of public transport normally include the public transport factors. These Manuals usually make it clear if factors are included, but if in any doubt the user should consult the Safety Regulation Group of the CAA.

29. It should be remembered that any 'limitations' given in the Certificate of Airworthiness, the Flight Manual, the Performance Schedule or the Owner's Manual/Pilot's Operating Handbook, are **mandatory on all flights.**

Performance Planning

30. A list of variables affecting performance together with guide line factors is shown in tabular form at the end of this Circular. These represent the increase in take-off distance to a height of 50 ft or the increase in landing distance from 50 ft. It is intended that the tabular form will be suitable for attaching to a pilot's clipboard for easy reference. **When specific corrections are given in the aeroplane's Manual, Handbook or Supplement, these must be considered the minimum acceptable.**

Take-off

Aeroplane weight. It is important that the actual weight stated on the weight and balance sheet for the individual aeroplane is used as the basis for calculations. The weight of individual aeroplanes of a given type can vary considerably dependent on the level of equipment. Using the example weight shown in the weight and balance section of the handbook is not satisfactory.

Guide line factor. Take-off distance will be increased by 20% for each 10% increase in aeroplane weight (a factor of x 1.2).

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The Effect of Variables

Aerodrome altitude. Aeroplane performance deteriorates with an increase in altitude and the pressure altitude at the aerodrome of departure should be used for calculations. This equates to the height shown on the altimeter on the ground at the aerodrome with the sub-scale set at 1013 mb.

Guide line factor. Take-off distance will be increased by 10% for each 1000 ft increase in aerodrome altitude (a factor of x 1.1).

Temperature. Aeroplane performance deteriorates with an increase in ambient temperature.

Guide line factor. Take-off distance will be increased by 10% for a 10°C increase in ambient temperature (a factor of x 1.1).

Wind. A tailwind increases the take-off distance.

Guide line factor. Take-off distance will be increased by 20% for a tailwind component of 10% of the lift-off speed (a factor of x 1.2).

NOTE:

Where the data allows adjustment for wind, it is recommended that not more than 50% of the headwind component and not less than 150% of the tailwind component of the reported wind be assumed. In some Manuals this factoring is already included and it is necessary to check the relevant section.

Slope. An uphill slope increases the ground run.

Guide line factor. Take-off distance will be increased by 10% for each 2% of uphill slope (a factor of x 1.1).

Surface. Grass, soft ground or snow increase rolling resistance and therefore the ground run.

Guide line factor. For dry grass (under 8 inches), the take-off distance will be increased by 20% (a factor of x 1.2).

For wet grass (under 8 inches), the take-off distance will be increased by 30% (a factor of x 1.3).

NOTE:

A take-off should not be attempted if the grass is more than 10 inches high.

For soft ground or snow the take-off distance will be increased by 25% or more (a factor of at least 1.25).

NOTE:

For surface and slope factors remember that the increases shown are to the take-off distance to a height of 50 ft. The correction to the ground run will be greater.

Flap setting. Read carefully any Supplement attached to your Manual, the take-off performance with or without the use of take-off flap shown in the main part of the Manual may not be approved for use by aeroplanes on the UK register.

Humidity. High humidity has an adverse affect on performance and this is usually taken into account during certification, however, there may be a correction factor applicable to your aeroplane. Check in the Manual.

Safety factors. It is recommended that the public transport factor should be applied for all flights. For take-off this factor is x 1.33 and applies to all Performance Group E aeroplanes. It is necessary to check the Manuals of Performance Group C and D aeroplanes to see if this factor is already included. Private Category aeroplanes in Groups B and F should apply the factors x 1.15 and x 1.25 respectively.

The above factors are cumulative and where several factors are relevant they must be multiplied. The resulting distance required can seem surprisingly high.

The Effect of Variables

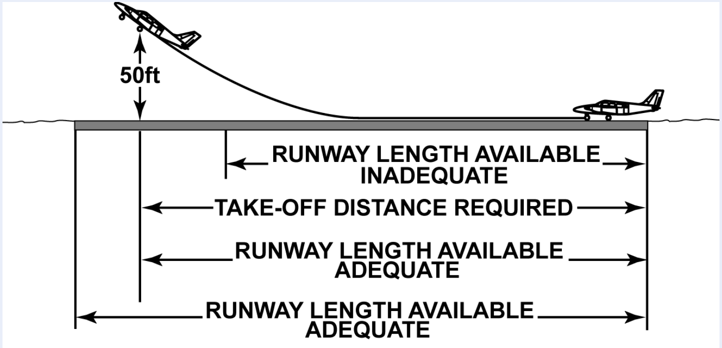
EXAMPLE

In still air, on a level dry runway at sea level with an ambient temperature of 10°C, an aeroplane requires a take-off distance to a height of 50 ft (TODR) of 390 m. This should be multiplied by the safety factor of 1.33 giving a TODR of 519 m.

The same aeroplane in still air from a dry, short grass strip (factor x 1.2) with a 2% uphill slope (factor x 1.1), 500 ft above sea-level (factor x 1.05) at 15°C (factor x 1.05), including the safety factor (factor x 1.33) will have a TODR of:

390 x 1.2 x 1.1 x 1.05 x 1.05 x 1.33 = 755 m

The pilot should always ensure that, after applying all the relevant factors including the safety factor, the take-off distance to a height of 50 ft (TODR) does not exceed the runway length available.



Climb

31. So that the aeroplane climb performance does not fall below the prescribed minimum, some Manuals give take-off and landing weights that should not be exceeded at specific combinations of altitude and temperature (WAT limits). Unless included in the Limitations section, these weight restrictions are mandatory only for public transport flights. **They are however recommended for private flights** and are calculated using the altitude and temperature at the relevant aerodrome. Where WAT limits are not given the following procedures are recommended:

(a) At the expected take-off and landing weights the aeroplane should be capable of a rate of climb of 700 ft/min if it has a retractable undercarriage, or 500 ft/min if it has a fixed undercarriage. The rates of climb should be assessed at the relevant aerodrome altitude and temperature in the en-route configuration at the en-route climb speed and using maximum continuous power;

(b) For an aeroplane with more than one engine, if conditions are such that during climb to, or descent from, the cruising altitude obstacles cannot be avoided visually, the aeroplane should be able to climb at 150 ft/min with one engine inoperative, at the aerodrome altitude and temperature.

Landing

Aeroplane weight. It is important that the actual weight stated on the weight and balance sheet for the individual aeroplane is used as the basis for calculations. The weight of individual aeroplanes of a given type can vary considerably dependent on the level of equipment. Using the example weight shown in the weight and balance section of the handbook is not satisfactory.

Guide line factor. Landing distance will be increased by 10% for each 10% increase in aeroplane weight (a factor of x 1.1).

Aerodrome altitude. Aeroplane performance deteriorates with an increase in pressure altitude.

Guide line factor. Landing distance will be increased by 5% for each 1000 ft increase in aerodrome altitude (a factor of x 1.05).

Temperature. Aeroplane performance deteriorates with an increase in ambient temperature.

Guide line factor. Landing distance will be increased by 5% for a 10°C increase in ambient temperature (a factor of x 1.05).

Wind. A tailwind increases the landing distance.

Guide line factor. Landing distance will be increased by 20% for a tailwind component of 10% of the landing speed (a factor of x 1.2).

NOTE:

Where the data allows adjustment for wind, it is recommended that not more than 50% of the headwind component and not less than 150% of the tailwind component of the reported wind be assumed. In some Manuals this factoring is already included and it is necessary to check the relevant section.

Slope. A downhill slope increases the landing distance.

Guide line factor. Landing distance will be increased by 10% for each 2% of downhill slope (a factor of x 1.1).

Surface. Grass or snow increase the ground roll, despite increased rolling resistance because brake effectiveness is reduced.

Guide line factor. For dry grass (under 8 inches), the landing distance will be increased by 20% (a factor of x 1.2).

32. For wet grass (under 8 in), the landing distance will be increased by 30% (a factor of x 1.3).

NOTE:

When the grass is very short, the surface may be slippery and distances may increased by up to 60% (a factor of x 1.6).

33. For snow the landing distance will be increased by 25% or more (a factor of at least 1.25).

NOTE:

For surface and slope factors remember that the increases shown are to the landing distance to a height of 50 ft. The correction to the ground roll will be greater.

Safety factors. It is recommended that the public transport factor should be applied for all flights. For landing this factor is x 1.67 for Group B aeroplanes and 1.43 for Groups C, D, E and F aeroplanes.

34. The above factors are cumulative and where several factors are relevant they must be multiplied. The resulting distance required may seem surprisingly high.

EXAMPLE 8-2

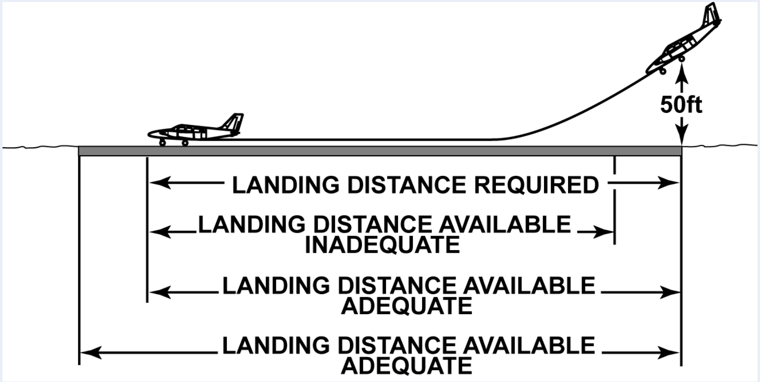
EXAMPLE

In still air, on a level dry runway at sea level with an ambient temperature of 10°C, an aeroplane requires a landing distance from a height of 50 ft (LDR) of 350 m. This should be multiplied by the safety factor of 1.4 giving a LDR of 501 m.

The same aeroplane landing in still air at a wet grass strip (factor x 1.3) 500 ft above sea level (factor x 1.025) at 20°C (factor x 1.05), including the safety factor (factor x 1.43) will have a landing distance of:

330 x 1.3 x 1.025 x 1.05 x 1.43 = 700 m

The pilot should always ensure that, after applying all the relevant factors including the safety factor, the landing distance required from a height of 50 ft (LDR) does not exceed the landing distance available.



Additional Information

Engine failure. The possibility of an engine failing during any phase of the flight should also be considered. Considerations should include the one engine inoperative performance of multi-engined types and the glide performance of single engined types. In the latter case, the ability to make a safe forced landing should be borne in mind throughout the flight.

Obstacles. It is essential to be aware of any obstacles likely to impede either the take-off or landing flight path and to ensure there is adequate performance available to clear them by a safe margin. The AGA section of the UK AIP includes obstacle data for a number of UK aerodromes.

Aerodromes distances. For many aerodromes, information on available distances is published in some form of aerodrome guide such as the AGA section of the UK AIP or commercially available Flight Guides. At aerodromes where no published information exists, distances should be paced out. The pace length should be established accurately or assumed to be no more than 2.5 ft. Slopes can be calculated if surface elevation information is available, if not they should be estimated. Prior to take-off it might be helpful to taxi the aeroplane from one end of the strip to the other and take an altimeter reading at each end. Most altimeters show differences down to 20 ft and to find the slope, simply divide altitude difference by strip length and give the result as a percentage. For example an altitude difference of 50 ft on a 2500 ft strip indicates a 2% slope. Be sure not to mix metres and feet in your calculation.

35. Operations from strips covered in snow, slush or extensive standing water should not be attempted without first reading AIC 61/1999 (Pink 195).

36. Where doubt exists on the source of data to be used or its application in given circumstances, advice should be sought from the Performance Section, Flight Department, Safety Regulation Group, of the Civil Aviation Authority.

FIGURE 8-8
Take-Off Distance Factorization

Condition	**Increase in** Take-Off to Height 50 Ft.	Factor
A 10% increase in Aeroplane Weight	20%	1.2
An increase of 1000 ft in Airfield Altitude	10%	1.1
An increase of 10°C in Ambient Temperature	10%	1.1
Dry Grass* - Up to 20cm (8ins) (on firm soil)	20%	1.2
Wet Grass* - Up to 20cm (8ins) (on firm soil)	30%	1.3
A 2% Uphill Slope*	10%	1.1
A Tailwind Component of 10% of Lift-Off Speed	20%	1.2
Soft Ground or Snow*	25% or more	1.25+

Effect on Ground Run/Roll will be greater.

The Effect of Variables

FIGURE 8-9
Landing Distance Factorization

Condition	**Increase in Landing Distance** from 50 Ft.	Factor
A 10% increase in Aeroplane Weight	10%	1.1
An increase of 1000 ft in Airfield Altitude	5%	1.05
An increase of 10°C in Ambient Temperature	5%	1.05
Dry Grass* - Up to 20cm (8ins) (on firm soil)	20%+	1.2
Wet Grass* - Up to 20cm (8ins) (on firm soil)	30% +	1.3
A 2% Downhill Slope*	10%	1.1
A Tailwind Component of 10% of Landing Speed	20%	1.2
Snow*	25% or more	1.25+

* Effect on Ground Run/Roll will be greater.

NOTE:

After taking account of the above variables it is recommended that the relevant safety factor (1.15 for Group B, 1.25 for Group F, 1.33 for Groups C, D and E for take-off, 1.67 for Group B and 1.43 for Groups C, D, E and F for landing) is applied.

NOTE:

Any deviation from normal operating techniques is likely to result in an increase in the distance required.

NOTE:

When the grass is very short, the surface may be slippery and distances may increase by up to 60% (a factor of x 1.6).

Practical Considerations

37. The assumptions made in the construction of the take-off graphs is that the aeroplane is fully serviceable and the pilot will adopt the recommended technique.

38. If the pilot uses a rolling technique to line-up and start the take-off whilst applying power, instead of a stationary start and applying full power against the brakes, then all the calculations will be invalidated. This is because some of the available distance is used up during the period that the engines are 'spooling up' to maximum take-off power and the calculations assume full take-off power over the whole distance.

39. When there is a large excess of TODA over normal TODR, the pilot may employ a reduced thrust technique for take-off. That is the power is not set to the maximum take-off setting but to that which will enable the next most limiting performance parameter to be attained. The aeroplane will take longer in time and distance to reach VLOF and will use the previously unused distance.

40. Should the high lift devices or anti skid system be unserviceable or the reverse thrust not be serviceable or not be permitted for noise abatement reasons, then the distances travelled during take-off will be increased. In the case of high lift devices, the distance to VLOF will be increased but for the non availability of the other equipment, it is the accelerate/stop distance that will be increased. Therefore, the TOW may have to be restricted to ensure the available distances are not exceeded.

41. When a flap setting greater than the optimum is used for take-off, then a larger amount of lift and drag is generated. This shortens the ground run significantly but reduces the TOD by only a small amount. The maximum angle of flap that may be used is usually 30° for short field take-offs. Although the lift is significantly increased during the ground run, so also is the drag. The acceleration will be slower than normal but because VR and VLOF are considerably lower than usual, the ground distance travelled is much shorter. Therefore the TOW as limited by the field lengths will be maximized.

42. When the field distances are unbalanced, the V1 will be higher than the V1 for the balanced field distance for that aerodrome. If the actual TOW is less than the field length limited TOW or range of V1's available, the lowest value being limited by TODA and the highest value by ASDA. The lowest value is normally used by jet aircraft because of the large excess of power available over power required; the higher value is used by turbo-prop aeroplanes that do not have this excess. Using a V1 below the balanced distance V1 ensures there is ample distance in which the aircraft can stop if take-off is abandoned. However, this distance is reduced if the V1 used is greater than the balanced field V1. The actual take-off distance is affected by the acceleration from V1 with one engine inoperative to reach VR which is determined by the TOW. This distance will be greater than that for a balanced field if the V1 used is greater. The reverse is true for the accelerate/stop distance.

43. Acceleration during the take-off ground run is reduced with high angles of attack and high weights. The angle of attack factor only affects aircraft with a tailwheel of which there are very few public transport aeroplanes still in existence.

Noise Abatement Procedures

44. The procedure to be adopted after take-off to ensure the aircraft noise remains at an acceptable level to those on the ground is determined by the position of the noise sensitive area relative to the end of the TODR. Procedure A is adopted if that area is some distance from the aerodrome. Those areas close to the aerodrome are accounted by using Procedure B. Both procedures have three segments and are illustrated at Figure 8-10.

45. **Procedure A.** The first segment, from screen height to 1500ft above the aerodrome surface level is conducted with all engines operating at take-off power/thrust with take-off flap set and flying at a speed of V2 + 10 to 20kts with the undercarriage retracted.

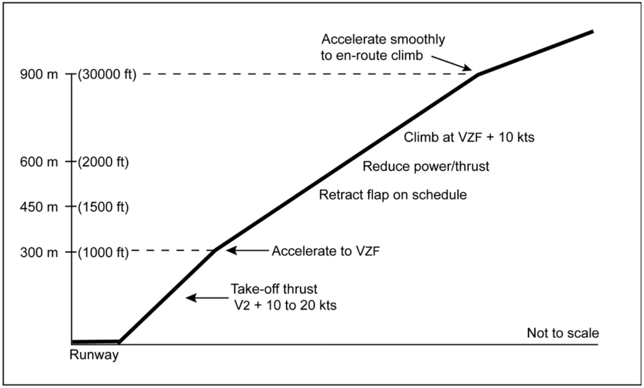
On attaining 1500ft the power/thrust is reduced to the climb setting. This is also the point at which the second segment begins. The power/thrust and speed remain the same as the first segment until the aeroplane reaches 3000ft. The third segment commences at this height and the aeroplane is then accelerated and the flaps retracted on attainment of the appropriate speed still climbing. The acceleration is continued until the en-route speed is achieved. The climb is continued to the en-route cruising altitude.

46. **Procedure B.** The first segment, from screen height to 1000ft above aerodrome level is conducted with take-off thrust and flap set at a speed of V_2 + 10 or 20kts. At 1000ft the aeroplane is accelerated to the minimum safe manoeuvring speed with zero flap (V_{ZF}) and the climb continued to 3000ft. During this segment the thrust must be reduced to normal climb thrust for high by-pass ratio engines, but for low by-pass ratio engines it must be reduced to less than the normal climb thrust yet not less than that required to maintain the final segment climb gradient of the one engine inoperative gross flight path. For aeroplanes having a slow rate of flap retraction, the thrust should be reduced at an intermediate flap setting. Throughout this segment the aeroplane must continue to accelerate to V_{ZF} + 10kts.

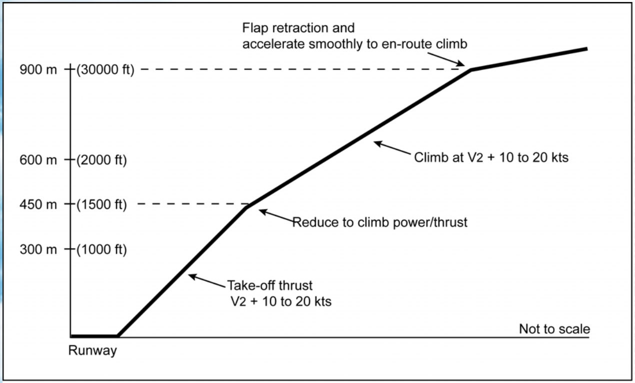
On attaining 3000ft the aeroplane is once again accelerated to the en-route climb speed and the climb continued to cruise level.

FIGURE 8-10

Noise Abatement Procedure



Noise abatement procedure 'B'



Noise abatement procedure 'A'

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Legislation Background

Legislation Background

1. Safety is of paramount importance. The purpose of scheduling performance is to ensure that all public transport aeroplane flights are conducted in the safest manner possible. That is to make certain that irrespective of the size, the number of engines or the number of passenger seats all public transport aircraft attained the same level of safety.

2. To discharge this commission it was necessary to take three measures:

(a) To divide all public transport aeroplanes into classes in which each aeroplane type has approximately the same performance capabilities.

(b) To devise legislation for both high and low performance aeroplanes, for each phase of flight, to produce the same level of safety of all classes.

(c) To determine the level of safety deemed acceptable and to specify the method to be used by the manufacturers to attain this level.

3. Currently the classification of aeroplanes is specified in JAR-OPS 1.470 and are as follows:

Aircraft Performance Classification

4. For the purposes of scheduled performance calculations all public transport passenger carrying aircraft are divided into five classes.

Class A. All multi-engined turbo propeller aeroplanes having 10 or more passenger seats **or** a maximum take-off weight exceeding 5700kgs. And **all** multi-engined turbo jet aeroplanes are included in Class A. Aircraft in this class are able to operate on contaminated runways and suffer an engine failure in any phase for flight without endangering the safety of the aeroplane. *[JAR-OPS 1.470 (a)]*

Class B. All propeller driven aeroplanes having 9 or less passenger seats **and** a maximum take-off weight of 5700 kgs. or less are in Class B. Any twin engined aeroplane included in this class which cannot attain the minimum climb standards specified in Appendix 1 to *JAR OPS 1.525 (b)* shall be treated as a single engined aircraft. Performance accountability for engine failure on multi-engined aircraft need not be considered below a height of 300ft *(IEM-OPS 1.535 Paragraph 1)*.

Single engined aeroplanes are prohibited from operating at night or in IMC (except under special VFR) and are restricted to routes or areas in which surfaces are available to permit a safe forced landing to be executed *[JAR–OPS 1.470 (b)]*.

Class C. This class comprises all piston engined aeroplanes with 10 or more passenger seats or a maximum TOW exceeding. 5700 kgs. Aircraft included in this class are able to operate on contaminated runways and suffer an engine failure in any phase of flight without endangering the aeroplane. *[JAR-OPS 1.470 (c)]*.

Unclassified. Aircraft which have specialised design features that affect the performance in such a manner that it is not possible to fully comply with the requirements of the appropriate class of aeroplanes are considered to be unclassified (eg seaplanes, supersonic aeroplanes). Specialised performance requirements applied to these aircraft ensure an equivalent level of safety is attained as though the aircraft had been included in the relevant class. *[JAR–OPS 1.470 (d)]*.

No Group. Multi-engined turbo propeller aeroplanes having 10 or more passenger seats **and** a maximum TOW of 5700 kgs or less unable to attain the performance requirements of Class A may continue to operate until 1 April 2000 provided the minimum performance requirements of Class B can be achieved. *[JAR–OPS 1.470 (e) and (f)].*

Joint Airworthiness Requirements

5. Because all Public Transport aeroplanes must attain the same level of safety it was necessary to produce individual legislation for each class of aeroplanes. This was done by producing complementary Operating Regulations and minimum acceptable performance requirements. The operating regulations are detailed in the **JAR-OPS Manual** and the minimum performance requirements in **JAR-25** for large aeroplanes and **JAR-23** for small aeroplanes.

The Scale of Probabilities

6. The level of performance deemed necessary for Public Transport Aeroplanes was derived from a scale of probabilities produced from the results of trials made at Boscombe Down. The original scale was published in British Civil Airworthiness Requirement, Section D which was superseded by the current table in **JAR-25**.

7. The target probability is 10^{-6} the 'Remote' probability. That is 1 incident per million flying hours, which **JAR-25** deems a 'Major' effect.

Performance Levels

8. There are three levels of performance - measured, gross and net. The basic datum from which the other two are derived is measured performance. The three levels are defined as:

Measured Performance. The average performance of an aeroplane or group of aeroplanes being tested by an acceptable method in specified conditions.

Gross Performance. The gross performance is such that the performance of any aeroplane of the type, measured at any time, is at least as likely to exceed the gross performance as not. It is the measured performance adjusted by 'Fleet Mean Power'.

Net Performance. Is gross performance modified in the manner prescribed in the relevant requirement to make appropriate allowance for those variations from the gross performance which are not dealt with in Operational Regulations.

Aeroplane Performance Assessment

9. Every new aircraft type is assessed by its manufacturer in terms of its performance capabilities in the various phases of flight – take-off, climb, cruise, descent and landing. From these assessments the manufacturer assembles performance data, obtained during tests flights, from which operating pilots can subsequently determine such values as the distances required for take-off and landing, the rate of climb, the optimum cruise altitude and so on.

10. Application of the performance data enables an operating pilot to determine whether, for example, the runway intended for take-off is long enough, or whether the aircraft's climb performance is sufficient to safely clear any obstacles along the intended climb-out flight path. Similarly, from the performance data, the pilot can determine whether a planned landing runway is of sufficient length. A perfectly executed take-off is of no use if the aircraft is unable to clear the trees beyond the end of the runway. Equally, a faultless approach and touchdown is valueless if the aircraft ends up in a ditch beyond the end of a too-short runway.

11. Safe operation of an aeroplane is dependent upon ensuring that the assessed performance is not exceeded in any given situation. This is especially important during the critical flight phases of take-off, climb-out, approach and landing.

12. The aeroplane's performance will be subject to many variable factors, including:

(a) Aircraft weight.

(b) Aerodrome altitude.

(c) Ambient air temperature and humidity.

(d) Wind speed and direction.

(e) Runway conditions (length, slope and surface).

(f) Flap setting.

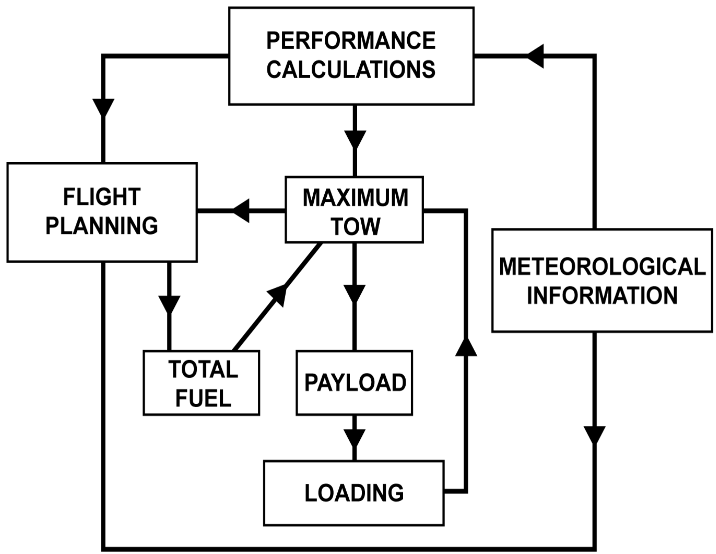
(g) CG position.

13. The performance data supplied by the manufacturer usually allows adjustments to be made to take account of these variables.

14. There is a direct relationship between the performance assessment of an aeroplane and the practical operation of that aeroplane. In other words, flight planning and loading are dependent upon the performance assessment.

15. To safely complete a planned flight, the aeroplane must be operated within its assessed performance capability. When planning a flight from aerodrome A to aerodrome B the pilot must consider such factors as the runway lengths available to take-off and landing, any obstacles to be safely cleared en-route and the load to be carried (aircraft weight) in terms of payload and fuel. The relationship between performance, flight planning and loading is illustrated diagrammatically at Figure 9-1.

FIGURE 9-1
The Relationship of Performance, Flight Planning and Loading



Self Assessed Exercise No. 1

QUESTIONS:

QUESTION 1.

Gross performance is:

(a) The average performance of a group of aeroplanes

(b) The measured performance of an aeroplane diminished by an amount prescribed in JAR's so that any aircraft of the type will exceed it by 70%

(c) The measured performance of an aircraft type adjusted so that any aircraft of the type has at least a 50% chance of exceeding it

(d) The net performance diminished to allow for variations of performance and different piloting techniques

QUESTION 2.

Clearway length is limited:

(a) To a maximum of 150% x TORA

(b) By a change in surface load bearing strength

(c) To a maximum of 50% x TODA

(d) By the first upstanding obstacle liable to damage the aircraft once it is airborne

QUESTION 3.

The minimum semi-width of stopway is:

(a) 60m

(b) 75m

(c) 90m

(d) Same as the associated runway

QUESTION 4.

A balance-field exists when:

(a) TODA = 150% × TORA

(b) TORA = EMDA

(c) TORA = TODA

(d) TODA = EMDA

QUESTION 5.

Field-lengths are referred to as unbalanced when:

(a) Clearway length exceeds stopway length only

(b) Clearway length equals stopway length

(c) Stopway length exceeds clearway length only

(d) Either stopway or clearway length exceeds the other

QUESTION 6.

TODA is:

(a) Always equal to runway length plus clearway length

(b) Always equal to runway length plus stopway length

(c) Never greater than 150% of TORA

(d) Never greater than 50% of TORA

QUESTION 7.

When used in scheduled performance calculations the wind is always factorised by:

(a) 50% for tailwind; 150% for headwind

(b) 150% for tailwind; 100% for headwind

(c) 150% for tailwind; 50% for headwind

(d) 50% for tailwind; 50% for headwind

QUESTION 8.

VMCG is determined for an aircraft type by the manufacturers and accounts:

(a) The nose wheel steering to maintain directional control

(b) The use of aerodynamic means and nose wheel steering to maintain directional control

(c) The use of aerodynamic means with a maximum of 10× of bank to maintain directional control

(d) The use of primary aerodynamic controls to maintain directional control

QUESTION 9.

Given: Surface wind velocity 340(M)/20 kt. The runway in use 28. The factored wind component is:

(a) 5 kt head

(b) 5 kt tail

(c) 10 kt head

(d) 17 kt head

QUESTION 10.

The target probability for scheduled performance is described as:

(a) 10^{-3}; minor effect, reasonably probable

(b) 10^{-6}; major effect, remote probability

(c) 10^{-9}; hazardous effect, extremely remote probability

(d) 10^{-9}; catastrophic effect, extremely remote probability

QUESTION 11.

The length of stopway is not limited by:

(a) The first upstanding non-frangible obstacle

(b) A deterioration of load bearing strength

(c) 50% of the runway length

(d) A ditch or depression

QUESTION 12.

The width of the clearway either side of the extended runway centre-line at UK aerodromes is:

(a) 60m expanding to 75m

(b) 75m expanding to 90m

(c) A 75m rectangle

(d) A 90m rectangle

QUESTION 13.

The maximum length of clearway is:

(a) 50% of TORA

(b) 150% of TORA

(c) 50% of EMDA

(d) 100% of EMDA

QUESTION 14.

Aerodrome elevation 3250ft amsl, QNH 1025 hPa. The pressure altitude using 30ft per hPa is:

(a) 3604ft

(b) 3250ft

(c) 2896ft

(d) 2650ft

QUESTION 15.

Which of the following statements is the correct definition of the take-off distance

(a) The distance from VR to screen height

(b) The sum of TORA and stopway lengths

(c) The total distance from BRP to the end of the clearway

(d) The distance from BRP to screen height

QUESTION 16.

Given: Runway 27, threshold elevation 423ft, TORA 1800m, EMDA 2000m, TODA 2200m. Runway 09 threshold elevation 329ft, TORA 1600m, EMDA 1800m, TODA 2000m. The runway slope of runway 27 is:

(a) 1.6% downhill

(b) 1.3% downhill

(c) 1.6% uphill

(d) 1.8% downhill

QUESTION 17.

The speed required to obtain the maximum gradient of climb is:

(a) V2

(b) V3

(c) VX

(d) VY

QUESTION 18.

The distance BD in the Figure 227 in the Reference Book is:

(a) EMDA

(b) Stopway

(c) Clearway

(d) TODA

QUESTION 19.

The semi-width BE in Figure 227 in the Reference Book is:

(a) 60m

(b) 75m

(c) 90m

(d) 150m

QUESTION 20.

The distance AC in Figure 227 in the Reference Book is:

(a) TORA

(b) EMDA

(c) TODA

(d) Clearway

QUESTION 21.

Compared with take-off on a level runway an upsloping runway will cause:

(a) An increase in TORR and a decrease in TODR

(b) An increase in TORR and an increase in TODR

(c) A decrease in TORR and an increase in TODR

(d) A decrease in TORR and a decrease in TODR

QUESTION 22.

VAT is:

(a) The speed at which the pilot aims to cross the threshold at screen height, when landing with one engine inoperative

(b) The speed at which the pilot aims to cross the threshold at screen height, when landing with all engines operating

(c) The speed at which the pilot aims to cross the threshold at screen height, when landing

(d) The speed at which the pilot aims to touchdown at the threshold, when landing

QUESTION 23.

The distance from the commencement of take-off to screen height is:

(a) The measured TOD

(b) The net TODR

(c) The gross TODR

(d) None of the above

QUESTION 24.

If flap is decreased from 10× to 0× for take-off:

(a) VLOF and V2 will decrease

(b) VLOF and V2 will increase

(c) VLOF will decrease and V2 will increase

(d) VLOF will increase and V2 will decrease

QUESTION 25.

With reference to the climb, in comparison with still-air a tailwind will:

(a) Increase the rate of climb

(b) Decrease the rate of climb

(c) Increase the gradient of climb

(d) Decrease the gradient of climb

QUESTION 26.

At screen height on landing, with both engines operating normally, the desired speed is:

(a) VATO

(b) VAT1

(c) VMCL

(d) VMCL1

QUESTION 27.

What will be the most limiting on landing weight:

(a) A headwind on a concrete surface

(b) A headwind on a grass surface

(c) A tailwind on a concrete surface

(d) A tailwind on a grass surface

QUESTION 28.

Compared to calm conditions, all other conditions being constant, the effect of a 10kt headwind will be:

(a) Increase the gradient of climb and increase the time taken to climb to a given altitude

(b) Increase the gradient of climb and decrease the time taken to climb to a given altitude

(c) Increase the gradient of climb but the time taken to a given altitude will be unaffected

(d) Decrease the gradient of climb but the time taken to climb to a given altitude will be unaffected

QUESTION 29.

Take-off run is:

(a) From VLOF to screen height

(b) From VLOF to the first obstacle

(c) From the start of the take-off run to screen height

(d) From the start of the take-off run to VLOF

QUESTION 30.

EAS is defined as:

(a) The equivalent airspeed corrected for density error

(b) The speed shown on the ASI corrected for instrument error

(c) The indicated airspeed corrected for position error

(d) The calibrated airspeed corrected for "adiabatic compressible flow"

QUESTION 31.

Rate of climb is defined as:

(a) A change of height over a given time period

(b) A change of height over a given distance

(c) A change of distance over a given time period

(d) A change of distance over a given height

QUESTION 32.

Given: Gradient of climb in still air 5%; TAS 200kt, groundspeed 250kt. The wind effective gradient is:

(a) 4%

(b) 5%

(c) 6.25%

(d) 7%

QUESTION 33.

Screen height is:

(a) The height of an imaginary screen at the end of TODA which an aircraft should clear with the undercarriage down

(b) The height of an imaginary screen at the end of TODR which an aircraft must clear with the undercarriage down

(c) The height of an imaginary screen at the end of TODA which an aircraft should clear with the undercarriage up

(d) The height of an imaginary screen at the end of TODR which an aircraft must clear with the undercarriage up

QUESTION 34.

At a fixed pressure altitude compared with still-air, a headwind will:

(a) Increase the climb gradient

(b) Decrease the climb gradient

(c) Not affect the climb gradient

(d) Increase the rate of climb

QUESTION 35.

At a fixed pressure altitude an increase of temperature will:

(a) Increase the climb gradient

(b) Decrease the climb gradient

(c) Not affect the climb gradient

(d) Increase the rate of climb

QUESTION 36.

The effect of a forward C of G is to:

(a) Increase range

(b) Decrease range

(c) Have no effect on range

(d) Increase endurance

QUESTION 37.

When operating from a contaminated runway:

(a) Use the normal VR and V2

(b) Do not take-off if depth of dry snow exceeds 15mm

(c) Take-off is permitted up to depths of 60mm of water, slush or wet snow

(d) Increase VR and V2 by 10kt

QUESTION 38.

Compared to landing on short dry grass, landing on long wet grass requires a __________ LDR, because of ________. The words to complete the sentence are:

(a) Shorter, more retardation by the grass

(b) Longer, less efficient braking

(c) Longer, less retardation by the grass

(d) Shorter, spray impingement drag

QUESTION 39.

The definition of density altitude is:

(a) The altitude in the standard atmosphere at which the prevailing density would occur

(b) The altitude in the standard atmosphere at which the atmospheric pressure would occur

(c) The height at which the prevailing density occurs

(d) The altitude in the standard atmosphere at which the prevailing temperature would occur

QUESTION 40.

A decrease in ambient temperature will …… the landing WAT gradient and …… the LDR. The words required to correctly complete the sentence are:

(a) Increase; decrease

(b) Increase; decrease

(c) Decrease; decrease

(d) Decrease; increase

ANSWERS:

ANSWER 1.

(c) Page 9-3 Paragraph 8

ANSWER 2.

(d) Page 5-3 paragraph 8

ANSWER 3.

(d) Page 5-2 paragraph 3

ANSWER 4.

(d) Page 5-8 paragraph 20

ANSWER 5.

(d) Page 5-8 paragraph 21

ANSWER 6.

(c) Page 5-4 paragraph 12

ANSWER 7.

(c) Page 5-15 paragraph 39

ANSWER 8.

(d) Page 7-2

ANSWER 9.

(a) Page 5-15 paragraph 39

ANSWER 10.

(b) Page 9-3 Paragraph 7

ANSWER 11.

(c) Page 5-2 paragraph 3

ANSWER 12.

(b) Page 5-3 paragraph 8

ANSWER 13.

(a) Page 5-3 paragraph 8

ANSWER 14.

(c) Page 5-14 paragraph 32

ANSWER 15.

(d) Page 7-2 Figure 7-1

ANSWER 16.

(d) Page 5-10 paragraph 26

ANSWER 17.

(c) Page 7-8

ANSWER 18.

(c) Page 5-5 Figure 5-1

ANSWER 19.

(b) Page 5-5 Figure 5-1

ANSWER 20.

(b) Page 5-5 Figure 5-1

ANSWER 21.

(b) Page 8-5 paragraph 15

ANSWER 22.

(c) Page 7-7

ANSWER 23.

(a) Page 7-2 Figure 7-1

ANSWER 24.

(b) Page 8-2 paragraph 5

ANSWER 25.

(d) Page 8-4 paragraph 11

ANSWER 26.

(a) Page 7-7

ANSWER 27.

(d) Page 8-13

ANSWER 28.

(c) Page 8-4 paragraph 11

ANSWER 29.

(d) Page 7-2 Figure 7-1

ANSWER 30.

(d) Page 7-1

ANSWER 31.

(a) Change of height in given time period usually in feet per minute

ANSWER 32.

(a) Page 8-4 WE gradient = $\frac{5}{250}$ x 200 = 4%

ANSWER 33.

(b) Page 6-1

ANSWER 34.

(a) Page 8-4

ANSWER 35.

(b) Page 8-6 para 19

ANSWER 36.

(b) Forward CG increases trim drag and power required which increases the fuel flow thus range is reduced

ANSWER 37.

(a) Page 4-15 paragraph 38(k)

ANSWER 38.

(b) Page 8-14 para 31

ANSWER 39.

(a) Page 6-1

ANSWER 40.

(a) Page 8-13

Take-off Class ‘B’ Aeroplanes

Take-off Field-Length Requirements

Take-off Class 'B' Aeroplanes

NOTE:

This class of aeroplane includes all propeller driven aeroplanes having 9 or less passenger seats and a maximum take-off weight of 5700 kgs. or less. Any twin-engined aeroplane included in this class which cannot attain the minimum climb standards specified in Appendix 1 to *JAR-OPS 1.525 (b)* shall be treated as a single-engined aeroplane. Performance accountability for engine failure on a multi-engined aeroplane need not be considered below a height of 300 ft. *(IEM-OPS 1.535 Paragraph 1)*.

NOTE:

Single-engined aeroplanes are prohibited from operating at night or in IMC (except under special VFR), and are restricted to routes or areas in which surfaces are available to permit a safe forced landing to be executed *[JAR-OPS 1.470 (B)]*.

1. A single-engined aeroplane is not permitted to operate at night or in instrument meteorological conditions (IMC) unless under special Visual Flight Rules. A twin-engined aeroplane unable to comply with the climb requirements of the next chapter will be considered to be single-engined.

2. There are two aspects of the take-off calculations that must be obeyed. They are the minimum field-length requirements and the minimum climb gradient requirements. The climb gradient requirements are included in Chapter 11.

Take-off Field-Length Requirements

All take-off calculations must take into account:

(a) Aerodrome pressure altitude and ambient temperature.

(b) Runway slope, surface type and surface condition.

(c) 50% of any headwind and 150% of any tailwind. This will already be accounted in the wind grid.

(d) The surface factorization to be used of 1.2 for dry grass and 1.3 for wet grass.

3. The runway slope is limited to ± 2% for normal operations, however, the JAA may approve slopes in excess of this if the correction factor is acceptable. *[AMC-OPS 1.530 (c) (5)]*.

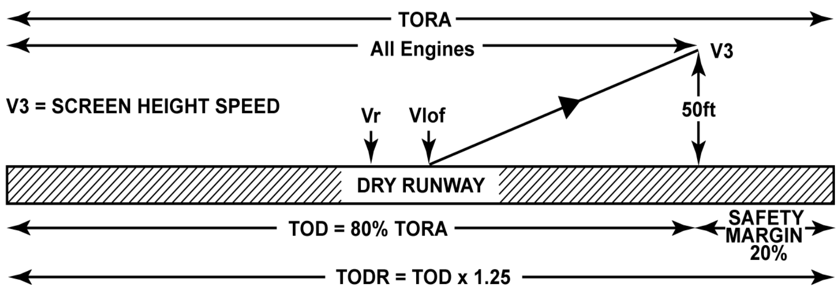
4. Take-off on a contaminated runway should be avoided whenever possible. Although the Flight Manual may provide information for calculations to be made for such take-offs, the Commander should take into consideration factors such as the state of the overrun area, obstacles after take-off and the cloud base. *[IEM-OPS 1.530 (c) (4)]*.

5. Performance accountability for engine failure need not be made below a gross height of 300 ft. [*IEM-OPS 1.535*].

Dry or Damp Paved Runways. The gross take-off distance required (TODR) must not exceed any of the following distances on a dry or damp runway:

(a) With no stopway or clearway – 80% of TORA i.e. Net TODR = Gross TODR x 1.25. *[JAR-OPS 1.530 (b) (1)]*. This means that the aeroplane must reach a speed of V3 at a screen height of 50 ft. within 80% of the length of TORA leaving 20% for safety reasons.

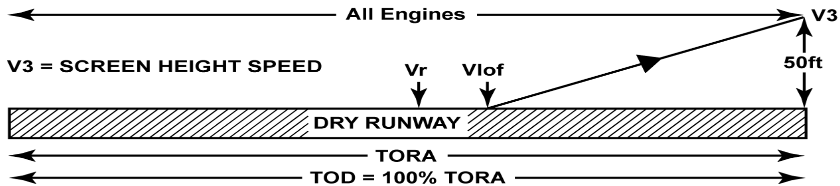
FIGURE 10-1
Gross TODR (No Stopway or Clearway)



(b) With stopway and/or clearway available the field-length limited TOW is limited by the most restrictive of:

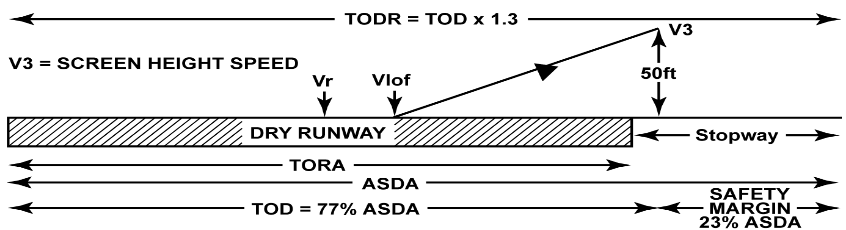
(i) 100% of TORA i.e. Net TODR = Gross TODR = TORA *[JAR-OPS 1.530 (b) (2) (I)]*. This means the aeroplane must reach screen height 50 ft at V3 speed by the end of TORA. See Figure 10-2.

FIGURE 10-2
Gross TODR with Stopway and/or Clearway - TORA Restriction



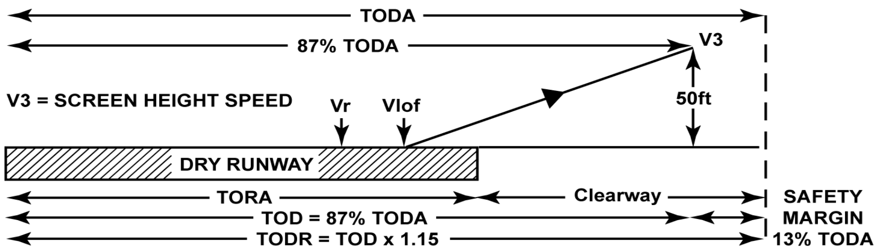
(ii) 77% of ASDA i.e. Net TODR = Gross TODR x 1.3 *[JAR-OPS 1.530 (b) (2) (ii)]*. This means the aeroplane must reach the end of the gross TODR in 77% of the accelerate/stop distance available. See Figure 10-3.

FIGURE 10-3
Gross TODR with Stopway and/or Clearway -ASDA Restriction



(iii) 87% of TODA i.e. Net TODR = Gross TODR x 1.15 *[JAR-OPS 1.530 (b) (2) (iii)]*. This means the aeroplane must reach the end of the gross TODR in 87% of the take-off distance available. See Figure 10-4.

FIGURE 10-4
Gross TODR with Stopway and/or Clearway - TODA Restriction



Runways Surfaces other than Wet or Dry or Damp Pavements. In the absence of information provided by the Manufacturers, for surfaces other than dry, hard surfaces the gross TODR should not exceed:

(a) With no stopway or clearway:

(i) Dry grass surface– 67% of TORA (Net = Gross x 1.5).

(ii) Wet grass surface – 61.5% of TORA (Net = Gross x 1.625).

(b) With stopway and/or clearway the gross TODR must not exceed the shorter of the distances for the appropriate surface:

(i) Dry grass surface:

(a) 83% TORA(Net = Gross x 1.20).

(b) 64% ASDA(Net = Gross x 1.56).

(c) 72.5% TODA(Net = Gross x 1.38).

(ii) Wet grass surface:

(a) 77% TORA(Net = Gross x 1.3).

(b) 59% ASDA(Net = Gross x 1.69).

(c) 67% TODA(Net = Gross x 1.5).

[AMC-OPS 1.530 (c) (4)].

Take-Off Calculations - Class 'B' Aeroplanes

6. All take-off calculations are made using the instructions and graphs in CAP 698. For Class 'B' aeroplanes these are on pages 6 to 10 for the single-engined piston (SEP 1) aeroplane and pages 18 to 26 for the multi-engined piston (MEP 1) aircraft.

7. For all graphs, irrespective of aeroplane type, which contain reference lines whenever moving in the direction of the example arrows always travel to the reference line first and then to the condition. Travelling in a direction opposite to the example arrows move to condition first and then to reference line.

8. If factors have to be applied for the nature of the surface or for runway slope when calculating a distance, multiply the graph result by the factors. When calculating a weight, divide the available distance by the factors before entering the graph.

Take-Off Distance Calculations

9. Follow the instructions and example on page 7 of CAP 698. Notice on the graph that the wind component grid has already been factorised 50% for a headwind and 150% for a tailwind. Also it is possible from the final grid to determine both to TORR and the TODR.

10. Now complete the following examples of this type of calculations. Be extremely careful that you select the correct graph for the configuration and that you interpret the scales correctly.

EXAMPLE 10-1

EXAMPLE

Aerodrome pressure altitude 3000ft; Ambient temperature +20°C; Wind component 10kt head; Runway slope 1% uphill; Surface - wet, grass; Flap setting 0°; Take-off weight 3300lbs.

Calculate the TODR for an SEP 1.

SOLUTION

Figure 2.1 Page 9 CAP 698

Graphical distance = 2000ft

Slope factor = x 1.05

Surface factor = x 1.3

TODR = 2730ft

EXAMPLE 10-2

EXAMPLE

Use the same details as Example 10-1; TOW 3500lbs

Calculate the TODR for an MEP 1

SOLUTION

Figure 3.1 Page 21 CAP 698

Graphical distance = 1550ft

Slope factor = x 1.05

Surface factor = x 1.3

TODR = 2115.8ft

Take-Off Weight Calculations

11. Before attempting to use the appropriate graph, the available distances must be defactored in accordance with JAR-OPS 1 to determine which is the most restrictive on TOW. The complete calculation procedure is detailed on Page 8 of CAP 698 for the SEP 1 and Page 24 for the MEP 1.

12. Complete the example calculations before attempting the practice examples on the following page. Once again, make sure you select the correct graph and be careful when using the scale. Remember when travelling in the opposite direction to the example arrows on the graph, to move to condition first and then to reference line.

EXAMPLE

Aerodrome pressure altitude 4000ft; Ambient temperature +35°C; Wind component 5kts tail; Runway slope 2% uphill; Flap setting 0°; Surface wet concrete; TORA 5000ft; ASDA 5800ft; TODA 5000ft

Calculate the field-length-limited TOW for an SEP 1

SOLUTION

	TORA	ASDA	TORA
Distance	5000ft	5800ft	5000ft
Slope factor	÷ 1.1	÷ 1.1	÷ 1.1
Surface factor	÷ 1.0	÷ 1.0	÷ 1.0
Regulatory factor	÷ 1.0	÷ 1.3	÷ 1.15
Defactored distance	4545ft	4056ft	3953ft
Distance used	3953ft		
FLL TOW	3500 lbs		

EXAMPLE 10-4

EXAMPLE

Aerodrome pressure altitude 5000ft; Ambient temperature +30°C; Wind component 10kt head; Runway slope 2% uphill; Flap setting 0°; Surface dry grass; TORA 3200ft; ASDA 3200ft; TODA 3200ft

Calculate the field-length-limited TOW for an MEP 1

SOLUTION

TORA 3200ft; Slope factor ÷ 1.1; Surface factor ÷ 1.2; Regulatory factor ÷ 1.25; Defactored distance = 3200 ÷ 1.1 ÷ 1.2 ÷ 1.25 = 1939ft. FLL TOW = 3800 lbs.

The Take-off Climb – Class B Aeroplanes

Obstacle Accountability Area

Climb Gradient Requirements

The Take-off Climb – Class B Aeroplanes

1. Performance accountability for engine failure does not have to be provided by the manufacturers below a height of 300 ft above reference zero (the horizontal plane at the surface at the end of the take-off distance required). Although an engine failure may occur before reaching this height, and adequate safety margins are built into the procedures, there may be no means of calculating the specific provision made for such an event. Most Flight Manuals only provide all engines operating data for take-off. The aeroplane is, therefore, assumed to reach screen height, 50 ft, at the end of TODR with all engines operating.

2. For the purpose of obstacle avoidance the 'see and avoid' principle is employed. That is if the obstacle can be seen it can be avoided. Hence if the visibility is poor or the cloud base low this method cannot be used. To ensure an absolutely safe flight it is assumed that on entering cloud a Class 'B' aeroplane suffers an engine failure. *[JAR-OPS 1.535 (a) (3)]*. The manufacturers are compelled to provide one engine inoperative climb data as required by *IEM-OPS 1.535.1* from a height of 300 ft to 1500 ft, but most will provide data from 200 ft.

3. According to Appendix 1 to *JAR-OPS 1.430 (a) (3) (ii)* the minimum acceptable visibility is determined by the cloud base which is 1500m above 300 ft, 1000m at 300 ft and 500m at 200 ft. These visibilities may be replaced by pilot assessment for the initial part of the take-off run.

4. At first sight the visibilities appear to be incorrect but the assumptions made are that if an engine fails below 300 ft the visibility quoted is the minimum considered necessary for the pilot to make a forced landing straight ahead, if necessary. Whereas above 300 ft in the event of engine failure the pilot will need to manoeuvre so as to circle and land.

5. A minimum visibility of 1500m is also required if the aeroplane is unable to comply with the obstacle clearance criteria *[IEM-OPS 1.535.2]* or if no positive take-off flight path can be constructed *[Appendix 1 to JAR-OPS 1.430 (a) (ii) Table 2 Note 1]*.

6. The net flight path therefore commences at 50 ft above reference zero and continues until the aeroplane attains 1500 ft above reference zero. If there is no cloud and the aeroplane remains in VMC the flight path is constructed using the all engines operating data. When there is cloud present the base must be 200 ft or higher and the visibility 500m or greater and the flight path should be constructed using the all engines operating data to the cloud base and the one engine inoperative data from the cloud base to 1500 ft above reference zero. *[JAR-OPS 1.535 (a) (3), (4) and (5)]*.

7. If a turn has to be scheduled the aeroplane may not be banked before the end of TODR and then only at an angle of 15° or less. The track change angle necessitating the turn dictates the shape of the obstacle accountability area as detailed below.

8. All flight path calculations must account the aerodrome pressure altitude, the ambient temperature, the TOW and 50% of any headwind or 150% of any tailwind. *[JAR-OPS 1.535 (d)]*.

9. The flight path in VMC is one segment from 50 ft to 1500 ft with all engines operating. The minimum cloud base is 200 ft in which net flight path comprises two segments, the first from 50 ft to the cloud base with all engines operating and the second from cloud base to 1500 ft with one engine inoperative. The gradients for all climb segments can be obtained from the Flight Manual but the gradient before reaching the cloud base must be factorized by multiplying by 0.77 or the distance travelled by multiplying by 1.3.

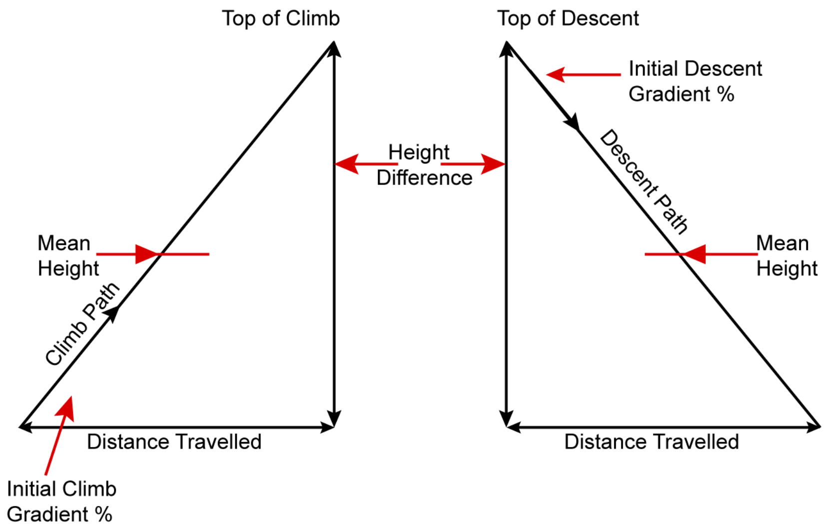
10. Often it is necessary to calculate either:

(a) The gradient of climb (or descent)

(b) The distance travelled in the climb (or descent).

The following text gives advice as to how to deal with such calculations. Although it is unecessary to remember the derivation of the following formulae, it is essential to memorise 2(a), 3 , 4 and 5.

FIGURE 11-1



(1) $\text{Gradient} = \dfrac{\text{Height difference in feet}}{\text{Distance travelled in feet}} \times 100$

(2) $\text{Distance in nm} = \dfrac{\text{Height difference in feet}}{\text{Gradient}} \times \dfrac{100}{6080}$ by transposition

To allow for the effect of the along track wind component then the formula becomes:

(2a) $\text{Distance in nm} = \dfrac{\text{Height difference in feet}}{\text{Still air gradient}} \times \dfrac{100}{6080} \times \dfrac{G/S}{TAS}$

OR

$$\text{Distance in nm} = \dfrac{\text{Height difference in feet}}{\text{Wind effective gradient}} \times \dfrac{100}{6080}$$

Thus formula (2a) may be used if the gradient of climb (or descent) is known, however, if only the rate of climb or descent is known, the formula (3) must be used.

(3) $\text{Distance in nm} = \dfrac{\text{Height difference in feet}}{\text{Rate of climb (or descent)}} \times \dfrac{G/S}{60}$

If only the rate of climb (or descent) is known it is possible to calculate the gradient of climb (or descent) by using formulae (2a) and (3).

$$\frac{\text{Height difference}}{\text{Still air gradient}} \times \frac{100}{6080} \times \frac{G/S}{TAS} = \frac{\text{Height difference}}{\text{Rate of climb (or descent)}} \times \frac{G/S}{60}$$

This can be simplified by cancellation.

$$\frac{1}{\text{Still Air Gradient}} \times \frac{100}{6080} \times \frac{1}{\text{TAS}} = \frac{1}{\text{Rate of Climb (or descent)}} \times \frac{1}{60}$$

and by transposing this formula it becomes

$$\text{Still Air Gradient} = \frac{\text{Rate of climb (or descent)}}{\text{TAS}} \times \frac{6000}{6080}$$

$$\text{Wind Effective gradient} = \frac{\text{Rate of climb (or descent)}}{\text{G/S}} \times \frac{6000}{6080}$$

These two formulae can be simplified for practical purposes to become:

(4) $$\text{Still Air gradient} = \frac{\text{Rate of climb (or descent)}}{\text{TAS}}$$

(5) $$\text{Wind Effective gradient} = \frac{\text{Rate of climb (or descent)}}{\text{G/S}}$$

To find the wind effective gradient from a still air gradient then the formula is:

$$\text{Wind effective gradient} = \text{Still air gradient x } \frac{\text{TAS}}{\text{G/S}}$$

EXAMPLE 11-1

EXAMPLE

Given: Still air gradient 5%; TAS 200 kts; G/S 250 kts.

Calculate the wind effective gradient.

SOLUTION

Wind effective gradient = $5 \times \frac{200}{250} = 4\%$.

EXAMPLE 11-2

EXAMPLE

Following an engine failure, a descent is to be made with one-engine inoperative from 16,000 ft pressure altitude, ambient temperature +8°C to 6000 ft pressure altitude, aeroplane weight 24,000 kgs and wind component 30kts headwind. CAS 101 kts. Rate of descent 157.5fpm.

Calculate:

(1) the mean wind effective descent gradient

(2) the descent distance travelled.

SOLUTION

(1)

At mean altitude 11,000ft, +18°C ambient
CAS 101kts = TAS 125 kts; G/S = 125 - 30 = 95kts

$$\text{Mean wind effective gradient of descent} = \frac{157.5}{95} = 1.66\%$$

(2)

$$\text{(a) Distance travelled} = \frac{10000}{1.66} \times \frac{100}{6080} = 99\text{nm} \quad \text{Formula (2a)}$$

$$\text{(b) Distance travelled} = \frac{10000}{157.5} \times \frac{95}{60} = 100.5\text{nm} \quad \text{Formula (3)}$$

Obstacle Accountability Area

FIGURE 11-2
The Obstacle Domain for NFP - Class 'B' Aeroplanes (The Obstacle Accountability Area)

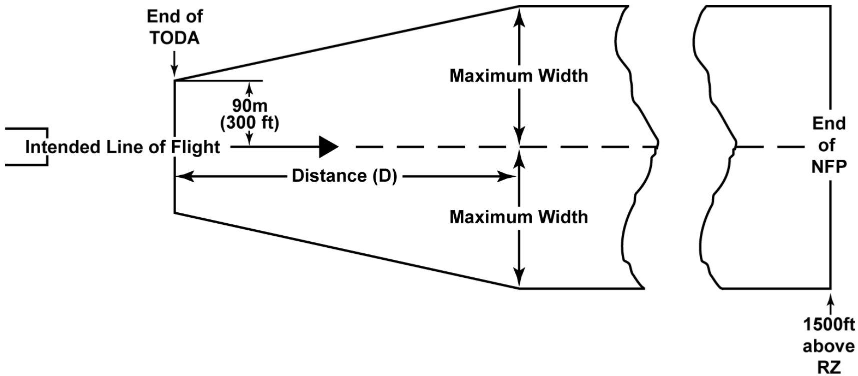


FIGURE 11-3
Obstacle Domain Maximum Semi-Width of [JAR OPS 1.535 (b) and (c)]

Change of Track Direction	0° - 15°	Over 15°
Able to maintain required Nav Accuracy	300m*	600m
All other conditions	600m	900m

* Or IMC if navigational aids enable the required track to be maintained with the same accuracy as visual guidance.

11. For visual guidance the operator must specify the minimum visibility and cloud ceiling for each procedure that will enable the crew to be able to continuously identify and maintain the required track with respect to ground reference points which will provide safe clearance of obstructions and terrain. The procedural path must account the aeroplane's ground speed, bank angle and any effect of wind. Limiting environmental conditions of lighting of the runway and obstructions must be specified. *[JAR-OPS 1.535 (b) (1) & (c) (1) Appendix 1].*

12. All obstacles encountered in the obstacle accountability area must be cleared by a minimum vertical interval of 50 ft.

Climb Gradient Requirements

FIGURE 11-4
Minimum Take-Off Climb Gradient Requirements [Appendix 1 to JAR-OPS 1.525 (b)]

Configuration	All Engines Operating	One Engine Inoperative	
Net Height	50 ft to Cloud Base/1500 ft	At 400 ft.	At 1500 ft.
Power	Take-off	Take-off	Maximum Continuous
Undercarriage	Extended unless retracted within 7 seconds	Extended unless retracted within 7 seconds	Retracted
Flaps	Take-off Position	Take-off Position	Retracted
Speed	1.1 VMC or 1.2 VS1 whichever is greater	1.1 VMC or 1.2 VS1 whichever is greater	1.2 VS1 or more
Minimum Gradient	4%	Measurably Positive	0.75%

Note. If a twin-engined aeroplane cannot comply with these minimum gradients it must be treated as a single-engined aeroplane and not operate at night or in IMC except under special VFR. *[JAR 23.63 (c) (1) and (2)].*

13. Before making any climb calculations it is important to read the instructions and follow through the examples in CAP 698 pages 11, 12, 27 and 28.

14. JAR-OPS 1.535(a)(4) requires all gradients to the cloud base to be factored by multiplying by 0.77. This is the same as multiplying the distance to the cloud base by 1.3.

EXAMPLE 11-3

EXAMPLE

Given: Aerodrome Pressure Altitude 2,000ft; Ambient Temperature +40°C; Wind Component 40kts Head; Obstacle Distance from the end of TODR 5,000ft; Obstacle Height above RZ 675ft:

Calculate: The maximum TOW that will ensure the SEP1 aeroplane clears the obstacle by the statutory minimum.

SOLUTION

$$\text{The gradient required} = \frac{\text{Height Difference}}{\text{Ground Distance}} \times 100$$

$$= \frac{675}{5000} \times 100 = 13.5\%$$

$$\text{Still Air Gradient Required} = \text{Wind Corrected Gradient} \times \frac{\text{G/S}}{\text{TAS}}$$

$$= 13.5 \times \frac{68}{108} = 8.5\%$$

Figure 2-3 page 13 CAP 698.

Obstacle Limited TOW = 3525 lbs

INDEX CONTENTS

EXAMPLE 11-4

EXAMPLE

Given: Aerodrome Elevation 3,000ft; QNH 1031 hPa; (use 30ft/hPa) Ambient Temperature -10°C; Wind Component 20kt. Tail; Take-off Weight 3375 lb.

Calculate : The Ground Distance taken by an SEP1 to reach 750ft above reference zero is:

SOLUTION

Aerodrome Pressure Altitude = Elevation + [(1013.2-QNH) x 30]

= 3000 - 534 = 2466ft.

CRP-5 IAS 100kt. Pressure Altitude 2500ft. Temperature -10°C TAS 100kt. WC 20kt. Tail. G/S = 100 + 20 = 120kt.

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

$$= \frac{700}{10.9} \times 100 = 6422\text{ft}$$

$$\text{Ground Distance} = 6422 \times \frac{120}{100} = 7706.4\text{ft} = 1.27\text{nm.}$$

$$\text{or Ground Distance} = \frac{\text{Height Difference}}{\text{ROC}} \times \frac{\text{G/S}}{60} = \frac{700}{1170} \times \frac{120}{6} = 1.2\text{nm}$$

EXAMPLE 11-5

EXAMPLE

Given: Aerodrome pressure altitude 6000ft; Ambient temperature +15°C; Take-off weight 4200lbs; Gear up; Flaps 0°; Cloud base 400ft above RZ; Wind Comp. 20kt head
Calculate: The distance travelled to 1500ft above RZ by an MEP 1

SOLUTION

ROC All engines take-off power = 1720 fpm
One engine inoperative take-off power = 326 fpm
One engine inoperative max. cont. power = 270 fpm

$$\text{Time to cloud base} = \frac{\text{Height Difference}}{\text{ROC}} \times 60 \text{ secs}$$

$$= \frac{350}{1720} \times 60 = 12 \text{ secs}$$

$$\text{Time cloud base to 1500ft} = \frac{1100}{326} \times 60 = 3\text{m. } 22 \text{ secs}$$

IAS = 92kts. TAS = 103kts. G/S = 103 - 20 = 83kts

$$\text{Distance to cloud base} = \frac{\text{Ht Diff}}{\text{ROC}} \times \frac{\text{G/S}}{60} = \frac{350}{1720} \times \frac{83}{60} = 0.28\text{nm} \times 1.3 = 0.364\text{nm}$$

$$\text{Distance cloud base to 1500ft} = \frac{1100}{326} \times \frac{83}{60} = 4.67\text{nm}$$

Total distance = 0.364 + 4.67 = 5.034nm

EXAMPLE

Given: Aerodrome pressure altitude 4000ft; Ambient temperature +30°C; Take-off weight 4600lbs; Gear up; Flaps 0°; Cloud base 800ft above reference zero; Wind comp. 25kt head; Obstacle at 14000ft from end of TODR and 1000ft above RZ.
Calculate: The vertical clearance of the obstacle by an MEP 1

SOLUTION

ROC All engines operating at take-off power 1500 fpm
One engine inoperative at take-off power 244 fpm
One engine inoperative at max. cont. power 200 fpm

$$\text{Time to cloud base} = \frac{\text{Ht Diff}}{\text{ROC}} \times 60 \text{ secs} = \frac{750}{1500} \times 60 = 30 \text{ secs}$$

$$\text{Time cloud base} = \frac{700}{244} \times 60 \text{ secs} = 2\text{m } 52 \text{secs}$$

IAS = 92kts. TAS = 102kts. G/S = 102 - 25 = 77kts

$$\text{Distance to cloud base} = \frac{\text{Height Difference}}{\text{ROC}} \times \frac{\text{G/S}}{60} \times 6080\text{ft} = \frac{750}{1500} \times \frac{77}{60} \times 6080$$

= 3901 ft x 1.3 = 5071.3ft   Distance cloud base to obstacle = 14000 - 5071.3 = 8928.7ft

$$\text{Height gain} = \frac{\text{Distance} \times \text{ROC} \times 60}{\text{G/S} \times 6080} = \frac{8928.7 \times 244 \times 60}{77 \times 6080} = 279.2\text{ft}$$

Height at obstacle = 800 + 279.2ft = 1079.2ft
Clearance of obstacle = 1079.2 - 1000 = 79.2 ft.

EXAMPLE 11-7

EXAMPLE

Given: Aerodrome pressure altitude 1000ft; Ambient temperature +20°C; Take-off weight 4700lbs; Gear up; Flap 0°; Cloud base 1600ft above RZ; Wind component 10kt head.

Calculate: The still-air climb gradient before reaching the cloud base for an MEP 1

SOLUTION

ROC all engines operating at T/O power = 1220 fpm. IAS = 92kts TAS = 112 kts.

$$\text{Gradient} = \frac{\text{ROC}}{\text{TAS}} \times \frac{6000}{6080} = \frac{1220}{112} \times \frac{6000}{6080} = 10.75\% \text{ x } 0.77 = 8.28\%.$$

En-Route - Class 'B' Aeroplanes

En-Route Regulations and Requirements

En-Route - Class 'B' Aeroplanes

1. The en-route phase is that which extends from the end of the take-off net flight path to a point 1000 ft. above the aerodrome at which a landing is to be made. When scheduling or planning this part of the flight the worst circumstance must be assumed, that is that an engine fails.

2. For twin-engined aeroplanes this will entail a descent until the aeroplane reaches the maximum altitude at which it can maintain level flight with one engine inoperative. On reaching this altitude it must be able to continue the flight to an aerodrome at which it can comply with all of the landing requirements without flying below the minimum safe altitude for the route.

3. A single-engined aeroplane suffering an engine failure would have to make a glide descent to a suitable area in which to make a forced landing. In so doing the pilot must avoid all high ground and obstacles during the descent. Thus a public transport single-engined aeroplane may not be flown at night or in IMC because the pilot would be unable to see any obstacle or high ground and take avoiding action. This restriction is in accordance with *JAR-OPS 1.525 (a)*, however, a further limitation is imposed to the en-route phase because of the see and avoid principle. To comply with this need then a flight may not be scheduled despite it being VMC if the route is above a layer of cloud that extends below the relevant minimum safe altitude. *[IEM OPS 1.542.1]*.

4. A pilot of twin-engined aeroplane on suffering an engine failure should take the following actions:

   (a) Carry out the emergency feathering or shut-down drills and select maximum continuous power on the live engine.

(b) Maintain level flight and allow the speed to decay to 'drift-down' speed i.e. the speed recommended by the manufacturers for the descent.

(c) Maintain the aeroplane in a level attitude at this speed. The drift-down path will be relatively steep initially and will become shallower until the aeroplane eventually is able to maintain altitude at this speed. This altitude is referred to as 'stabilising altitude'.

5. The actions to be taken by the pilot of a single-engined aeroplane, in the event of engine failure, are as follows:

(a) Carry out the emergency feathering drills.

(b) Maintain level flight and allow the speed to decay to the 'drift-down' speed.

(c) Select a suitable area in which to make a forced landing, taking into account:

(i) Clearance of intervening terrain.

(ii) The wind direction. Land into wind if possible to reduce the groundspeed.

(iii) The type of surface.

(iv) The position of any built-up areas.

(v) The position of the sun if it is a low altitude. Avoid approaching into sun.

(vi) Carry out the aeroplane forced landing drills.

6. The rules and regulations applicable to the en-route phase of flight are formulated to attain ultimate safety. For all drift-down path and stabilising altitude calculations only the net values are those that must be compared with high ground or with MSA.

En-Route Regulations and Requirements

Multi-Engined Aircraft

7. In the event of an engine failure en-route the aeroplane must be capable of continuing the flight at or above the MSA to a point 1000 ft. above an aerodrome at which the landing performance requirements can be attained. *[JAR-OPS 1.540 (a)]*.

8. To show compliance the following regulations apply *[JAR-OPS 1.540 (b)]:*

(a) The altitude at which the aeroplane is assumed to be cruising may not exceed that altitude at which the rate of climb (ROC) is 300 fpm with all engines operating at maximum continuous power.

(b) The net gradient of the drift-down path is the gross gradient diminished by 0.5%.

Single-Engined Aircraft

9. In the event of engine failure the aeroplane must be capable of gliding to an area where a safe forced landing can be made i.e. land for a landplane. *[JAR-OPS 1.542 (a)]*.

10. To show compliance with this regulation *[JAR-OPS 1.542 (b)]:*

(a) The altitude at which the aeroplane is assumed to be flying with maximum continuous power set does not exceed the altitude at which the rate of climb (ROC) is 300 fpm.

(b) The net gradient of the drift-down path is the gross gradient of descent increased by 0.5%.

Landing - Class 'B' Aeroplanes

Landing - Class ‘B’ Aeroplanes

1. There are two requirements for landing that must be observed when making calculations. The first is the weight-altitude-temperature (WAT) limitation on landing weight and the second is the limitation imposed by the field-lengths.

The WAT Limit

2. The limitation on landing weight caused by the requirement to comply with the minimum climb gradients in the event of a missed approach or a balked landing is determined by the ambient density. There are two minimum gradients that must be attained. *[Appendix 1 to JAR-OPS 1.525 (b)]*. They are:

All-engines-operating. 2.5% at the power available 8 seconds after opening the throttles, flying at V_{REF} with the undercarriage extended and with the flaps at the landing position. This is to be at the aerodrome pressure altitude.

One-engine-inoperative. 0.75% at 1500 ft. above the aerodrome surface level. This is with one engine inoperative, maximum continuous power set on the remaining live engine, flaps and undercarriage retracted at a speed of 1.2 V_{S1}.

The Field-Length Limit

3. The requirements regarding the field-length limit are sub-divided into those for landing on a dry runway and those pertaining to landing on a wet or contaminated runway. However, all require accountability of the following for compliance with the appropriate regulation:

(a) 50% of any headwind and 150% of any tailwind.

(b) Runway surface condition and type.

(c) Runway slope in the landing direction.

Dry Runway Requirements

4. The landing distance (LD) is measured from the threshold to the point at which the aeroplane comes to rest. The normal approach path is a 3° (5.0%) descent to arrive at screen height of 50 ft. at a speed of VREF, which is the greater of VMC and 1.3 VMS0. However, steep approaches in excess of 4.5° are permitted and may have a screen height between 50 ft. and 35 ft.

Hard Surface Runway. The landing distance required on a hard, dry surface may not exceed 70% of the landing distance available. This leaves 30% of the landing distance available as a safety margin. Thus the net landing distance required = gross landing distance required x 1.43.

5. Landings are permitted on a grass surfaced runway provided it is firm soil on which only wheel impressions occur with no rutting, provided the grass length does not exceed 20 cm. However, if such is the case the gross distance required must be factored by a further multiplication by 1.15 i.e. the factor to be applied to a landing distance required on dry grass is 1.43 x 1.15 = 1.64. In other words the landing distance required must not exceed 61% of the landing distance available which leaves 39% for a safety margin. *[AMC-OPS 1.550 (b) (3)]*.

FIGURE 13-1
Landing Distance - Dry Hard Surfaces

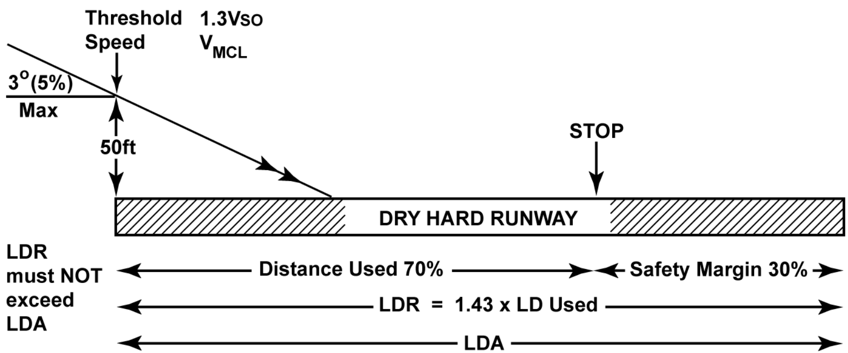
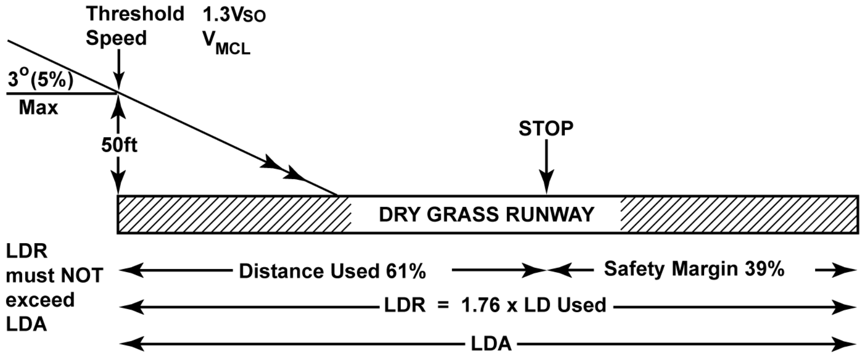


FIGURE 13-2
Landing Distance - Dry, Grass Surface



Steep Approaches. At particular aerodromes the JAA may approve a steep approach procedure having a glideslope of 4.5° or more and a specified screen height between 50 ft. and 35 ft. For such an approval the flight manual must contain any limitations on such an approach and a means of determining the landing distance required.

6. Each aerodrome at which this procedure is to be employed must have at least a visual guidance system and specified weather minima for each runway.

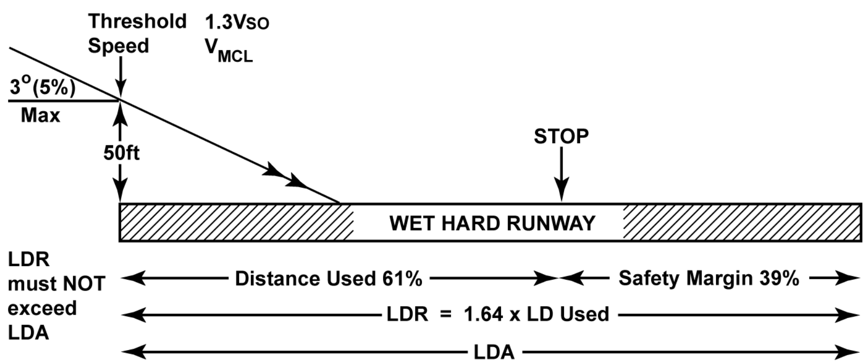
Wet Runway Requirements

[JAR-OPS 1.555 (a) and (c)]

7. If the meteorological actual report or forecast for the estimated time of arrival indicates that the runway will be wet, that is covered in water less than 3mm deep, then the LDR is to be 115% of the dry runway LDR. However, if the landing distance available is less than this amount but greater than the dry runway LDR then it may be used provided that the Flight Manual includes specific additional information regarding the LDR on wet runways.

The calculated LDR must still comply with the requirement of *JAR-OPS 1.550 (a)* i.e. the factorisation for a wet hard runway is 1.43 x 1.15 = 1.6445 and for a wet grass runway is 1.64 x 1.15 = 1.89.

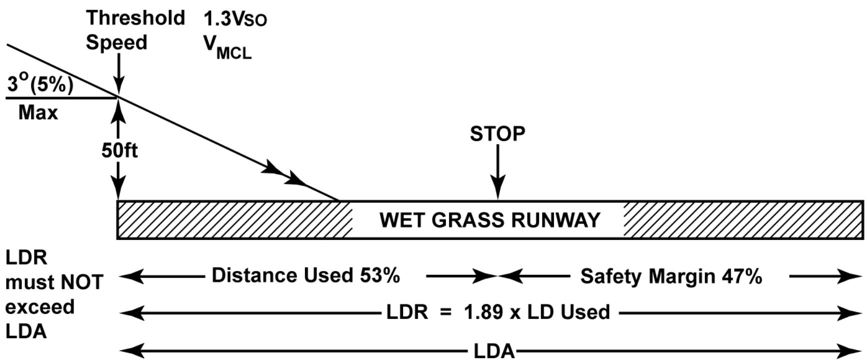
FIGURE 13-3
Landing Distance - Wet, Hard Surface



Wet Hard Surface

8. The landing distance required my not exceed 61% of the landing distance available, leaving a 39% safety margin i.e. Net LDR = Gross LDR x 1.6645.

FIGURE 13-4
Landing Distance - Wet, Grass



Wet Grass Surface

9. The landing distance required may not exceed 53% of the landing distance available, leaving a 47% safety margin i.e. Net LDR = Gross LDR x 1.89.

Contaminated Runway Requirements

[JAR-OPS 1.555 (b)]

10. If the meteorological actual report or forecast conditions for the estimated time of arrival imply that the runway is likely to be contaminated, that is 25% of the surface covered with a significant depth of contaminant, then the landing distance required shall be determined using the data provided by the manufacturers and approved by the JAA in the aeroplane Flight Manual provided it does not exceed the landing distance available.

Short Landing Operations

11. Any short landing operations must have the approval of the JAA before being planned or executed. The distance used for the calculation of the field-length-limited landing weight is the sum of the declared landing distance available and the length of the declared safe area. See Figure 13-5. The screen height at the beginning of the declared safe area is a minimum of 50ft.

12. **Declared Safe Area.** This is an area approved by the aerodrome authority situated on the approach path to the runway and adjoining the beginning of the LDA. It has a maximum length of 90 metres and a minimum semi-width equal to the runway width either side of the extended runway centre-line. It must be free of obstructions, ditches and depressions which could be hazardous to an aeroplane undershooting the runway. The surface slope of the area must not exceed 5% upward or 2% downward in the direction of landing. It does not require the same load bearing strength as the LDA.

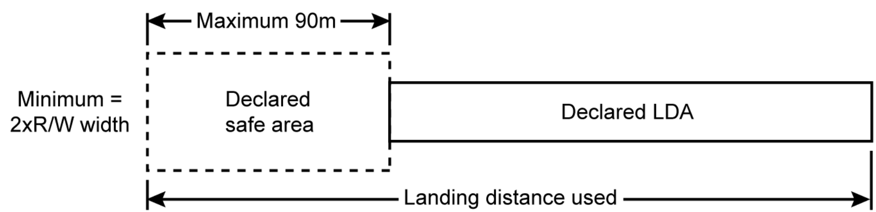
13. **Short Landing Requirement.** In addition to the normal landing requirements operators must comply with the following:

(a) **Weather.** The weather minima must be specified and approved for each runway and shall not be less than VFR or the non-precision minima.

(b) **Pilot.** The requirements that must be complied with regarding briefing and experience must be detailed in the Operations Manual.

(c) **Safety.** The JAA may impose such additional conditions that it considers for safety reasons, accounting the aircraft type, the approach aids and the missed approach/ baulked landing considerations. *Appendix 2 to JAR-OPS 1.550(a).*

FIGURE 13-5
Landing Distance Used



14. Now read the instructions and complete the examples in CAP 698, Pages 14, 15 and 35 to 41.

EXAMPLE 13-1

EXAMPLE

Given: Aerodrome pressure altitude 6000ft; Ambient temperature +10°C; Wind component 20kts head; Landing weight 3100lbs; Runway slope 2% down; Surface wet grass

Calculate: The landing distance required for a normal landing with an SEP 1

SOLUTION

Figure 2.4 Page 15 CAP 698

Graphical distance = 1400ft

Slope factor = x 1.1

Surface type factor = x 1.15

Surface condition factor = x 1.15

Regulatory factor = x 1.43

Landing distance required = 2912ft

EXAMPLE 13-2

EXAMPLE

Given: Aerodrome pressure altitude 4000ft; Ambient temperature -20°C; Wind component 10kts tail; Runway slope 2% uphill; Surface dry pavement; LDA 2900ft.

Calculate: The field-length limited landing weight from overhead the destination for an SEP 1

SOLUTION

Landing distance available 2900ft

Slope factor = ÷ 1.0

Surface type factor = ÷ 1.0

Surface condition factor = ÷ 1.0

Regulatory factor = ÷ 1.43

Corrected LDA = 2028ft

Figure 2.4 Page 15 CAP 698

FLL Landing weight = 3100lbs

EXAMPLE 13-3

EXAMPLE

Given: Aerodrome pressure altitude 3000ft; Ambient temperature +10°C; Landing weight 3200lbs; Wind component 5kts tail; Runway slope 1% down; Surface dry pavement

Calculate: The landing distance required for a normal landing for an MEP 1

SOLUTION

Figure 3.9 Page 40 CAP 698

Graph distance = 2600ft

Slope factor = x 1.05

Surface factor = x 1.0

Regulatory factor = x 1.43

LDR = 2600 x 1.05 x 1.0 x 1.43 = 3904ft

Landing - Class 'B' Aeroplanes

EXAMPLE

Given: Pressure altitude 5000ft; Ambient temperature -10°C; Landing weight 3900lbs; Wind component 15kts head; Runway slope 2% uphill; Surface type grass, condition wet.

Calculate: The landing distance required for a short landing for an MEP 1

SOLUTION

Figure 3.10 Page 41 CAP 698

Graph distance = 1750ft

Slope factor = x 1.0

Surface type factor = x 1.15

Surface condition factor = x 1.15

Regulatory factor = x 1.43

Landing distance required = 3310ft

Landing - Class 'B' Aeroplanes

EXAMPLE

Given: Aerodrome pressure altitude 2000ft; Ambient temperature +30°C; Wind component 10kts head; Runway slope 1% up; Surface - paved, wet; LDA 3750ft

Calculate: Overhead the destination determine the field-length limited landing weight for a normal landing for an MEP 1

SOLUTION

Landing distance available 3750ft

Slope factor = ÷ 1.0

Surface factor = ÷ 1.15

Regulatory factor = ÷ 1.43

Corrected LDA = 2280ft

FLL Landing weight = 3900lbs

EXAMPLE 13-6

EXAMPLE

Given: Aerodrome pressure altitude 2000ft; Ambient temperature +20°C; Wind component 5kts head; Runway slope 2% down; Surface wet grass; Landing distance available 4300ft

Calculate: Overhead the destination determine the field-length limited landing weight for a short landing for an MEP 1

SOLUTION

Landing distance available 4300ft

Slope factor = ÷ 1.1

Surface factor = ÷ 1.15

Condition factor = ÷ 1.15

Regulatory factor = ÷ 1.43

Corrected LDA = 2067ft

FLL Landing Wt = 4100 lbs

Landing - Class 'B' Aeroplanes

EXAMPLE

Given: Aerodrome pressure altitude 2000ft; Ambient temperature + 30°C; Wind velocity 040/15; Surface condition dry;

Runway 06; LDA 1128m; Grass; 1% Uphill slope

Runway 10/28; LDA 1020m; Concrete; 0.5% down/0.5% up slope

Calculate: The maximum scheduled landing weight for a normal landing for an MEP 1

SOLUTION

Runway	06	10
LDA	3700ft	3346ft
Slope factor	÷ 1.0	÷ 1.025
Surface factor	÷ 1.15	÷ 1.0
Condition factor	÷ 1.0	÷ 1.0
Regulatory factor	÷ 1.43	÷ 1.43
Corrected LDA	2250ft	2283ft
W. Component	14kt head	7kt head
X Wind comp.	5kt L to R	12.5kt L to R

	Still Air	Forecast Wind
Runway 06	3200lbs	3950lbs
Runway 10	3250lbs	3650 lbs
Highest	3250 lbs	3950 lbs
Lowest	3250 lbs	

Field length limited landing weight 3250 lbs

EXAMPLE 13-8

EXAMPLE

Conditions as for Example 13-7 except Runway 06 LDA 820m. Runway 10/28 LDA 870m.

Calculate: The maximum scheduled landing weight for a short landing for an MEP 1

SOLUTION

Runway	06	10
LDA	2960ft	2854ft
Slope factor	÷ 1.0	÷ 1.025
Surface factor	÷ 1.15	÷ 1.0
Condition factor	÷ 1.0	÷ 1.0
Regulatory factor	÷ 1.43	÷ 1.43
Corrected LDA	1636 ft	1947 ft
Wind component	14kt head	7kt head
X Wind component	5kt L to R	12.5kt L to R

	Still air	Forecast wind
Runway 06	<3000lbs	3530lbs
Runway 10	3400lbs	3750lbs
Highest	3400lbs	3750lbs
Lowest	3400lbs	

Field length limited landing weight 3400 lbs

Performance Class ‘A’ Aeroplane Take-Off

Performance Class 'A' Aeroplane Take-Off

Regulations

Class 'A' Aeroplanes

NOTE:

All multi-engined turbo-propeller aeroplanes having 10 or more passenger seats or a maximum take-off weight exceeding 5700 kgs. And all multi-engined turbo-jet aeroplanes are included in Class A. Aeroplane in this Class are able to operate on contaminated runways and suffer an engine failure in any phase of flight without endangering the safety of the aeroplane. [JAR-OPS 1.470 (a)]

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1. Sufficient data will be provided in the aeroplane flight manual to enable calculations to be made for:

(a) Engine failure at any time in flight.

(b) Contaminated Runway Operations.

Take-Off – Field-Length Limitation

2. The following regulations apply to take-off:

   (a) The maximum clearway length is restricted to 50% of TORA.

   (b) A single value of V1 is to be used for the rejected and continued take-off cases.

   (c) The maximum TOW for a wet or contaminated runway must not exceed that for a dry runway under the same conditions.

   (d) Distances required must not exceed distances available i.e. TORA>TORR; EMDA>EMDR; TODA>TODR.

   (e) The maximum TOW must not exceed the WAT (Weight-Altitude-Temperature) limited TOW.

   (f) Undercarriage retraction is not permitted before 3 seconds after VLOF or reaching screen height whichever is the later.

3. When making take-off calculations:

   (a) All available distances must be reduced by the amount of runway alignment reduction appropriate to aeroplane type before starting calculations.

   (b) Aerodrome pressure altitude and ambient temperature must be used.

   (c) Runway slope, surface type and surface condition must be used.

(d) 50% of any headwind and 150% of any tailwind will be accounted in the wind component grid.

The Take-Off Requirements

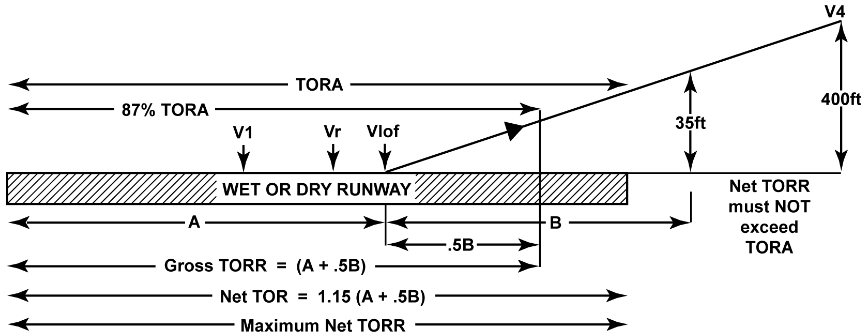
4. If the take-off distance includes a clearway, the take-off run is the greater of:

(a) **TORR** – All power units operating. The total of the gross distance from the start of the take-off run to the point at which VLOF is reached, plus one half of the gross distance taken from VLOF to the point at which the aircraft reaches a screen height of 35 ft at a speed of V2 consistent with the aircraft attaining V2 + 10 kts by 400 feet above reference zero, is factorized by 1.15 to obtain the all-power-units operating net TORR. This factorization ensures that the gross TORR is within 87% of TORA. *[JAR-25.113 (b) (2) and AMJ-25X1591(c) (ii)]*. See Figure 14-1.

(b) **TORR** – One Power Unit Inoperative (Dry Runway). The gross horizontal distance from the commencement of the take-off roll to a point equidistant between VLOF and the point at which a height of 35 ft above the take-off surface is reached on a dry runway, assuming the critical power unit is inoperative at VEF. *[JAR-25.113 (b) (1)]*. See Figure 14-2.

(c) **TORR** – One Power Unit Inoperative (Wet Runway). The gross horizontal distance from the commencement of the take-off roll to the point at which VLOF is reached on a reference wet hard surface, assuming the critical power unit becomes inoperative at VEF corresponding to VGO. *[AMJ-25X1591(c) (i)]*. See Figure 14-3.

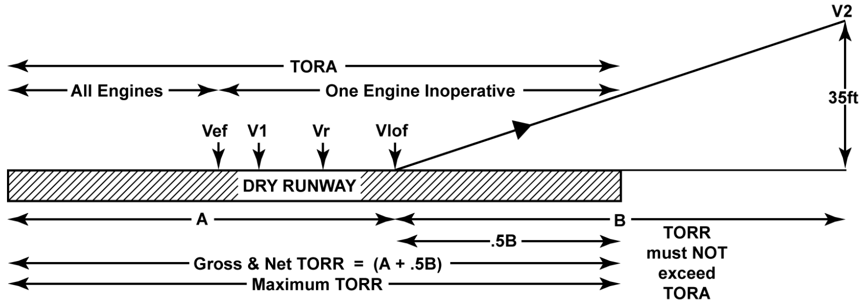
FIGURE 14-1
JAR TORR - All Power Units Operating



A = Gross Distance to VLOF
B = Gross Distance from VLOF to 35 ft

FIGURE 14-2

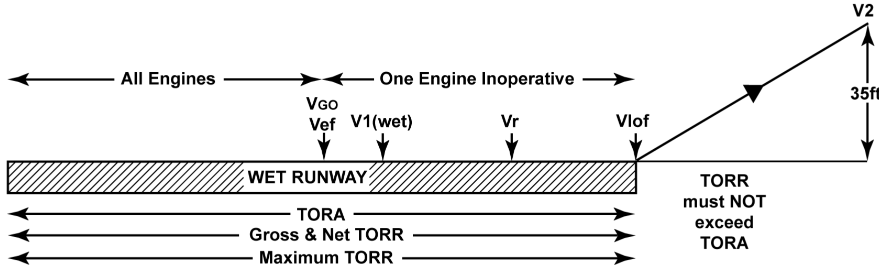
JAR TORR (Dry Runway) - One Engine Inoperative



A = Gross Distance to VLOF
B = Gross Distance from VLOF to 35 ft

FIGURE 14-3

JAR TORR (Wet Runway) - One Engine Inoperative



Accelerate/Stop Distance Required (ASDR)

5. With the implementation of JAR's a relatively new term has been introduced to Class 'A' performance to describe the minimum distance which the aircraft requires to come to rest in the case of an abandoned T/O. This is the Accelerate/Stop Distance Required (ASDR) which is the greatest of the following total distances.

The accelerate/stop distance on a dry runway is the greater of:

(a) **ASDR – All Engines Operating.** The sum of the distances required to accelerate from a standing start with all engines operating to V1 + 2 seconds, and to decelerate from this point to a full stop on a dry hard surface with all engines still operating. *[JAR-25.109 (a) (2)]*. See Figure 14-4.

(b) **ASDR – One Engine Inoperative.** The sum of the distance necessary to accelerate from a standing start with all engines operating to V1 plus the distance covered in a continued acceleration for two seconds from this point with one power unit inoperative, plus the distance taken to come to a full stop on a dry hard surface. *[JAR-25.109 (a) (1)]*. See Figure 14-5.

FIGURE 14-4
JAR ASDR - All Power Units Operating (Dry Runway)

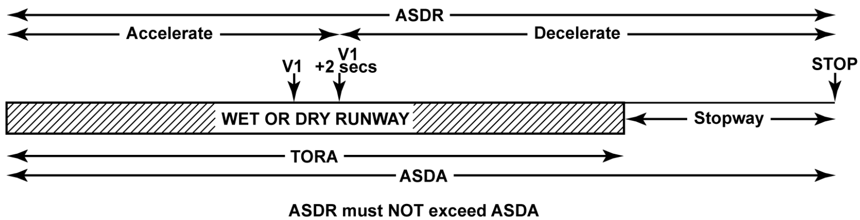
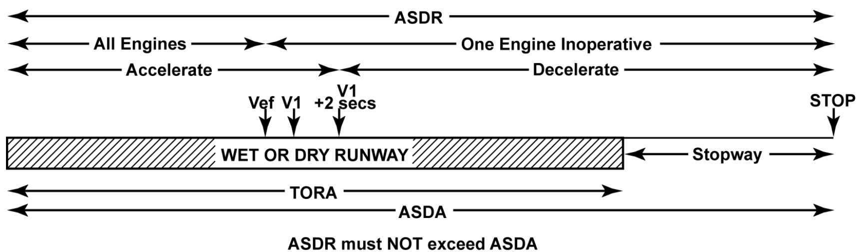


FIGURE 14-5
JAR ASDR - One Power Unit Inoperative (Dry Runway)



6. The accelerate/stop distance on a wet runway is the greater of:

(a) **ASDR – All Engines Operating.** The sum of the distances required to accelerate from a standing start with all engines operating to VSTOP + 2 seconds, and to decelerate from this point to a full stop on a wet hard surface with all engines still operating. *[AMJ-25X1591 (a) (ii)]*. See Figure 14-6.

(b) **ASDR – One Engine Inoperative.** The sum of the distance necessary to accelerate from a standing start with all engines operating to VSTOP plus the distance covered in a continued acceleration for two seconds from this point with one power unit inoperative, plus the distance taken to come to a full stop on a wet hard surface. *[AMJ-25X1591 (a) (i)]*. See Figure 14-7.

FIGURE 14-6
JAR ASDR - All Power Units Operating (Wet Runway)

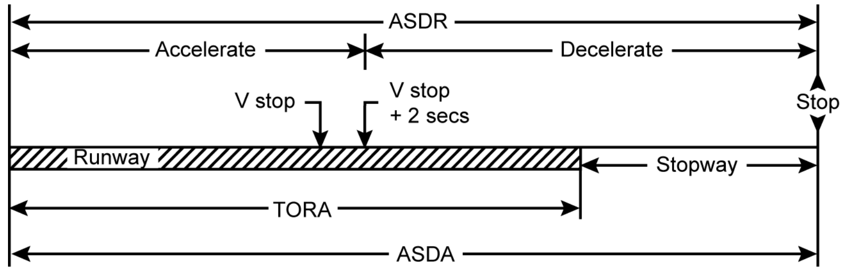
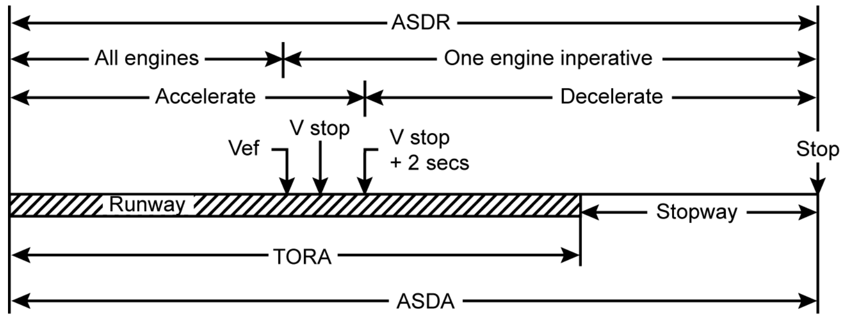


FIGURE 14-7
JAR ASDR - One Power Unit Inoperative (Wet Runway)



Take-Off Distance Required (TODR)

7. The Take Off Distance Required is the greatest of the following three distances: *[IEM-OPS 1.495 (a)]*

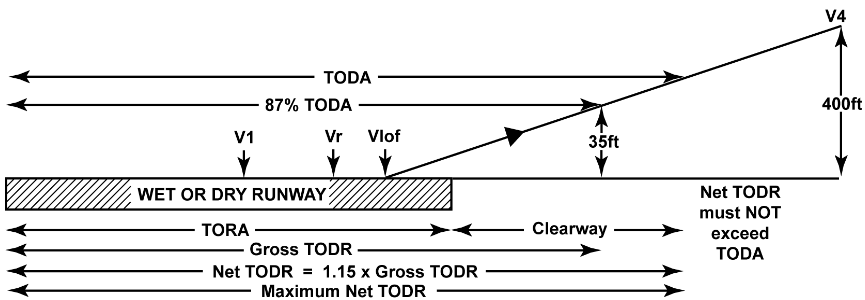
(a) **TODR – All Engines Operating.** 115% of the horizontal distance travelled, with all engines operating, to reach a height of 35 ft above the take-off surface level in such a manner that V4, (V2 + 10 kts), is achieved by 400 ft above the Take-Off surface level. *[JAR-25.113 (a) (2)]*. See Figure 14-8.

(b) **TODR – One Engine Inoperative (Dry Runway).** The horizontal distance from commencement of the take-off roll to the point at which the aircraft is 35 ft above the take-off surface, assuming the critical power unit fails at V1 on a dry hard surface. *[JAR-25.113 (a) (1)]*. See Figure 14-9.

(c) **TODR – One Engine Inoperative (Wet or contaminated Runway).** The horizontal distance from commencement of the take-off roll to the point at which the aircraft reaches 15 ft above the take-off surface level, assuming the critical power unit fails at V1 and a reference wet hard surface, achieved in a manner consistent with obtaining V2 by 35 ft. *[AMJ-25X1591 (b)]*. See Figure 14-10.

8. Only when an engine failure occurs at the most critical speed will the full distances available be required. The probability of this event occurring is also 'remote' and is held not to necessitate the gross distances required being factorized.

FIGURE 14-8
JAR TODR - All Power Units Operating



Performance Class 'A' Aeroplane Take-Off

FIGURE 14-9
JAR TODR (Dry Runway) - One Engine Inoperative

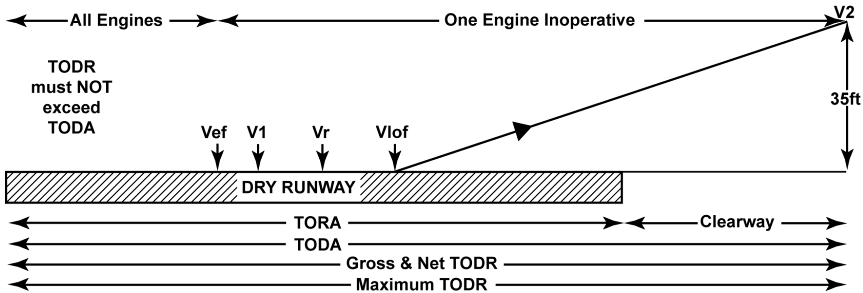
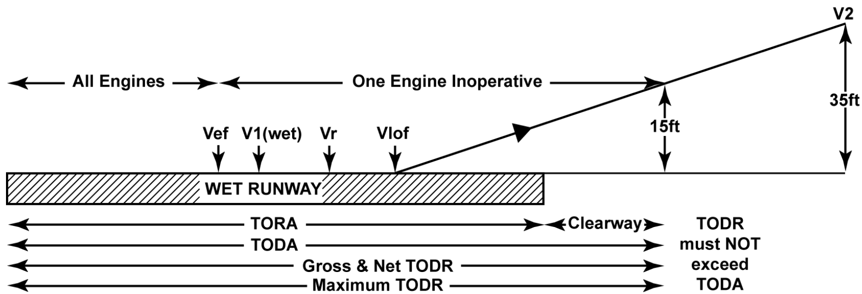


FIGURE 14-10
JAR TODR (Wet Runway) - One Engine Operative



Calculation of Field-Length Limited TOW

9. The take-off field length requirements specified in JAR25 must be complied with by the operator. To ensure this occurs the manufacturers encompass the requirements in a graph titled 'Take-off Performance Field Limit.' The assumptions made in the construction of the graph are:

(a) The critical power unit fails at V1.

(b) The remaining engine(s) are at maximum take-off power.

(c) The one engine inoperative take-off distance requirements for a jet-engined aeroplane are the most limiting.

(d) The distance available for use is TODA or if no clearway is available TORA.

(e) Runway slope 0%.

(f) Wind component 0 kts.

(g) The recommended flap setting is selected.

10. The graph provides correction grids in the prevailing conditions or configuration differ from those assumed. The wind correction grid is already factorized 50% of any headwind and 150% of any tailwind. As density grid is provided so that account can be made for the power available at the prevailing temperature at the aerodrome pressure altitude.

Calculation Procedure. Enter the carpet of the graph at the CAP698 page 55 at the field-length available. Travel vertically to the runway slope reference line then parallel the grid to the appropriate runway slope input. From this point continue vertically to the wind component reference line and parallel the grid lines to the prevailing along track wind component input. Now move vertically to the flap position reference line if 5° selected continue vertically, if 15° selected parallel the grid lines to 15° before continuing vertically. Draw a vertical straight line through the TOW grid. Now enter the left carpet at the ambient temperature proceed vertically to the aerodrome pressure altitude. From this point move horizontally right to the weight grid reference line. Now parallel the grid lines to intersect the vertical line just drawn through this grid. From this intersection move horizontally right to the field-length-limit brake release weight vertical axis. Read the field-length limited TOW and apply the corrections for air conditioning system, engine anti-icing and power management computer as tabulated, if necessary.

EXAMPLE 14-1

EXAMPLE

Given: TORA 9600 ft; R/W slope 1% up; Wind Component 20 kts Head; 15° Flap Selected; Ambient temperature + 33° C; Aerodrome pressure altitude 2000 ft. Air conditioning on Anti-Ice off. PMC on.

Calculate the field-length limited TOW.

SOLUTION

63,100 kgs

EXAMPLE 14-2

EXAMPLE

Given: Details as for Example 10-1 except flaps 5°.

SOLUTION

62,100 kgs

EXAMPLE 14-3

EXAMPLE

Given: Aerodrome pressure altitude 6000 ft; Ambient Temperature +2C; TORA 8200 ft; R/W slope 2% up wind component 5 kts. tail; 5° flap; ACS off; Anti-Ice on; PMC on. Calculate the field-length limited TOW.

SOLUTION

52,000 kgs + 550 kgs (ACS off) – 350 kgs (Anti-ice on) = 52,200 kgs.

EXAMPLE 14-4

EXAMPLE

Given: Aerodrome Pressure Altitude 7000 ft; Ambient Temperature - 10°C; TORA 7600 ft; Slope 2% down. Wind Component 20 kts. Head; 15° Flap; Acs on; Anti-ice on; PMC off. Calculate the field – length limited TOW.

SOLUTION

58,100 kgs - 350 kgs (Anti-ice) - 1660 kgs = 56,090 kgs.

EXAMPLE 14-5

EXAMPLE

Given: Aerodrome Pressure Altitude5000 ft; Ambient Temperature - 5°C; TORA 6200 ft; Slope 2% up. Wind Component 10 kts. Head; 15°flap; ACS off; Anti-ice on; PMC off. Calculate the field – length limited TOW.

SOLUTION

50,900 kgs + 550 kgs. (ACS off) - 350 kgs. (Anti-ice on) - 1660 kgs. = 49,440 kgs.

Tyre Speed Limited TOW

11. Most aeroplanes have a range of tyres that may be fitted. Those selected for use will depend on the area of the world in which most of the operator's flights will take place. This is because the range of surface temperatures, the nature of the surface and the range of aerodrome pressure altitudes will influence the decision on the type of tyre most suited to the area of operations. All types of tyre are subject to a maximum operating temperature, which if exceeded will cause the heat plugs to blow out and the tyre to deflate. Thus the maximum operating temperature of the tyre limits the maximum rotational velocity, because of the heat generated by surface friction, and therefore limits the maximum groundspeed. This maximum is usually stated in mph in American manuals. The graph at CAP698 page 59 is typical of this type of graph.

12. Groundspeed is directly influenced by the following factors:

(a) Air density – Low air density caused by high temperature, high pressure altitude or a combination of both increases the TAS for a given IAS. This causes the groundspeed to increase.

(b) Decreased flap setting causes a longer take-off ground run. Thus longer contact with the surface generates more heat due to surface friction.

(c) A tailwind will increase the groundspeed for a given TAS.

(d) Manual power management is less efficient than computer management.

13. The corrections to be applied to the basic tyre speed limited TOW are tabulated below the main graph, which accounts the air density. The graph used for this calculation is titled 'take-off performance tyre speed limit'.

EXAMPLE 14-6

EXAMPLE

Given: Aerodrome Pressure Altitude 2000 ft; Air Temperature + 33°C; 15° Flap Set; Wind Component 10 kts. tail; PMC off; 210 mph rated tyres.

SOLUTION

80,400 kgs – 1500 kgs (210 mph Rating & 15° Flap) – 6500 kgs. (10 kt Tailwind) – 250 kgs (PMC off) + 33°C) = 72,150 kgs.

EXAMPLE 14-7

EXAMPLE

Given: Aerodrome Pressure Altitude 6000 ft; Air Temperature + 20°C; 15° Flap Set; Wind Component 5kts Head; PMC Off; 210 mph rated tyres.

SOLUTION

72,700 kgs – 1500 kgs (210 mph rating & 15° Flap) + 2000 kgs (5 kts Headwind) – 270 kgs (PMC off) = 72,930 kgs.

The Calculation of V Speeds

14. The definitions of all the V speeds were stated in Chapter 7. However, it is essential to understand and apply the rules that govern the calculation of the take-off speeds which are:

(a) VMCG must not exceed VMCA.

(b) VMCG must not exceed V1.

(c) V1 must not exceed VR.

(d) V1 must not exceed VMBE.

15. Factors that directly influence the value of all of the speeds are weight, pressure altitude, ambient temperature and the use of the power management computer. Other influencing factors are runway slope and wind component, which affect V1 and the use of the air conditioning system which affects VMCG. The flap setting affects V1, VR and V2.

16. Most V speeds for take-off are either tabulated with mathematical corrections to be applied or presented graphically with correcting grids. The method used for the MRJT is a combination of both. See tables at CAP 698 pages 64 and 65. Separate pages show these combinations for each flap setting. A small graph on page 63 accounts the density i.e. pressure altitude and temperature. This determines which table of speeds to use each speed is precisely listed against the take-off weight of the aeroplane. A separate table at the top right of the page 64 and 65 lists the corrections to be made to the tabulated value of V1 for both runway slope and wind component. VMCG is shown in a table at the centre of the page with the method of correction detailed below the table. To correct VMCG, V1 and VR for PMC Off use the bottom table on Page 70.

EXAMPLE 14-8

EXAMPLE

Given: Aerodrome pressure Altitude 3000 ft; Ambient Temperature + 30°C; Runway Slope 2% uphill; wind component 5 kts. Tail; TOW 60,000 kgs; Flaps 5°; PMC on; A/C off;

SOLUTION

VMCG = 109 kts + 2kts. (A/C off) = 111 kts
V1 = 146kts + 2 kts (2% up) – 1kt (5 kts tail) = 147 kts
VR = 149 kts
V2 = 155 kts

EXAMPLE 14-9

EXAMPLE

Given: Details as for Question 1 except flaps selected 15°.

SOLUTION

VMCG = 109 kts + 2 kts. (A/C off) = 111 kts.
V1 = 139 kts + 2 kts. (2% up) – 1 kt (5 kts tail) = 140 kts
VR = 140 kts
V2 = 146 kts

EXAMPLE 14-10

EXAMPLE

Given: Aerodrome pressure altitude 5000 ft; Ambient Temperature + 20°C; Runway Slope 2% Down; Wind Component 10 kt. Tail; TOW 55,000 kgs; Flaps 15°; PMC on; A/C off;

SOLUTION

VMCG 109 kts. + 2 kts (A/C off) = 111 kts.
V1 131 kts - 2 kts. (2% down) - 2 kts (10 kts Tail) = 127 kts.
VR 133 kts.
V2 140 kts

EXAMPLE 14-11

EXAMPLE

Given: Aerodrome Pressure Altitude 5000 ft;
Ambient Temperature + 20°C; Runway Slope 2% Uphill
Wind Component 20 kts. Head; TOW 60,000 kgs; Flaps 15°; PMC on; A/C on.

SOLUTION

V_{MCG} 109 kts.
V_1 139 kts. + 2 kts. (2% up) + ½ kt. (20 kts. Head) = 141 ½ kts.
V_R 140 kts.
V_2 146 kts.
V_1 Restricted by V_R to 140 kts.

EXAMPLE 14-12

EXAMPLE

Given: Aerodrome Pressure Altitude 5000 ft;

Ambient Temperature +10°C; R/W Slope 2% Downhill;
Wind Component 10 kts tail; TOW 45,000 kgs; Flaps 15°; PMC off; A/C off.

SOLUTION

VMCG 109.5 kts. + 2 kts. (A/C off) + 1kt (PMC off) = 112.5 kts.
V1 116 kts. – 2kts (2% down) –2.6 kts. (10 kts. Tail) + 4 kts (PMC off) = 115.4 kts.
VR 118 kts + 1 kt (PMC off) = 119 kts.
V2 128 kts.

VMBE Limited TOW

17. The wheel braking system only operates efficiently up to a specified maximum brake temperature which is usually between 450°C and 500°C. At brake temperatures above this the system will fail to stop the aeroplane. The factors that adversely affect the operational efficiency of the system are those which cause the brake temperature to increase and are precisely the same as those that cause the tyre speed to become limiting. They are:

(a) Aerodrome Pressure Altitude.

(b) Aerodrome Surface Ambient Temperature.

(c) A Tailwind Component.

18. An increase of any of these factors causes the maximum brake energy speed, V_{MBE}, to decrease. Decision speed, V1, must never exceed V_{MBE}. If it does then the TOW must be reduced so that V1 equals V_{MBE}. The graph to be used is CAP 698 page 61.

EXAMPLE 14-13

EXAMPLE

Given: Aerodrome Pressure Altitude 5,600 ft; Ambient Temperature - 10°C; TOW 64,000 kgs; Runway Slope 2% Downhill; Wind Component 10 kts tail PMC off. Calculate VMBE.

SOLUTION

VMBE 165 kts - 10 kts (2% down) – 20 kts. (10 kts tail) – 1 kt PMC off = 134 kts.

EXAMPLE 14-14

EXAMPLE

Given: Aerodrome Pressure Altitude 6,000 ft; Ambient Temperature + 20°C; TOW 60,000 kgs.Runway 2% Down; Wind Component 10 kts. Tailwind; PMC off; Flaps 15°; V1 dry 138 kts.

Calculate VMBE Limited TOW.

SOLUTION

VMBE = 160 kts. –10 kts. (2% Downhill) – 20 kts. (10 kts.Tail) - 1 kt (PMC off) = 129 kts.

VMBE Limited TOW = 60,000 kgs. – (9 x 300) = 57,300 kgs

Contaminated Runway Corrections

19. A runway is not considered to be contaminated unless more than 25% of the runway surface is covered with a depth of 3 mm or more of water, slush or wet snow or 10 mm or more or dry snow. If the runway is contaminated then the predicted acceleration of the aeroplane on take-off may be in error due to spray impingement on the airframe and the wheels suffering rolling resistance from the contaminant. Not only is the acceleration affected, but in the event of an abandoned take-off, the ability of the aeroplane to stop in a safe distance is also adversely affected. It is impossible, in these circumstances, for the manufacturers to produce accurate V speeds for take-off. In particular V1

cannot be scheduled because V1 guarantees the ability of the aeroplane to continue the take-off or to safely abandon the take-off. No such guarantee can be given when the amount of drag and the coefficient of friction are unknown variable amounts. The manufacturers can only provide advisory information. This information for the MRJT is given in a tabular format for three depths of contaminant and titled "Slush/Standing Water Take-Off". They are valid for all flap settings, with the air conditioning on or off and assumes an engine failure at V1.

Calculation Procedure. To calculate the contaminated runway limited TOW and associated V1 it is first necessary to select the tables appropriate to the depth of the contaminant. Interpolation between tables in not permitted, therefore, if the depth of contaminant exceeds that for a particular table then the next table of greater depth must be used i.e. the more adverse depth must be assumed. Although the maximum depth of contaminant permitted for take-off is 15 mm, and if such is the case, then the 13 mm depth tables would have to be used, however it should be noted that the results will be slightly optimistic. Use CAP 698 pages 72 and 73. The procedure is then:

(a) Enter the left table with the actual TOW in the left column and travel right to the column appropriate to the aerodrome pressure altitude. Interpolating, if necessary.

(b) Read the weight and V1 Reductions. Apply corrections to actual TOW and V1 for this weight. If this is in the shaded area of the table move to the right table.

(c) Enter the right table with TODA and travel right to the aerodrome pressure altitude, interpolating if necessary, to determine the maximum contaminated runway take-off weight.

(d) The contaminated runway take-off weight is the lower of (b) or (c) above.

(e) If (c) is limited make V1 = VMCG. If not, then the corrected V1 from (b) is used provided it is not less then VMCG, if it is then V1= VMCG. No matter which was limiting; V1 is the maximum abandonment speed and is of an advisory nature only, and means that for an abandoned take-off the aeroplane **should** stop before the end of the stopway is reached.

EXAMPLE 14-15

EXAMPLE

Given: Aerodrome Pressure Altitude 4000 ft; TORA 6000 ft; Ambient Temperature 0°C; Runway Slope 2% Uphill Wind Component 10 kts head; TOW 48000 kgs; Flap 15°; PMC on; A/C on; 10 mm. Slush.
Calculate contaminated runway TOW and maximum abandonment speed.

SOLUTION

From the normal dry runway tables: CAP 698 Page 65
VMCG = 111 kts.
V1 = 121 kts.
V2 = 131.5 kts.

From 13mm Table
Left Table At 48000 kgs.@ 4000' – 8,800 kgs. 0kts Adjustment to V1.
Right Table At 6000 ft.@ 4000' max TOW 45,000 kgs. Limited by VMCG.
Reduced TOW = 48000 – 8800 = 39,200 kgs.

Revised V speeds at Reduced TOW 39,200 kgs

V1 = 104 kts. + 1 kt. (2% Up) = 105 kts. Restricted by VMCG = 111 kts.
VR = 110 kts. Restricted by VMCG = 111 kts.
V2 = 122 kts.

Maximum Abandonment Speed = 111 kts. TOW 39,200 Kgs.

EXAMPLE

Given: Aerodrome Pressure Altitude 6000 ft; TORA 6200 ft. Ambient Temperature -5°C; Runway Slope 2% Downhill; Wind Component 5 kts.Tail; TOW 55000 kgs; 5mm. Water; Flaps 15°; PMC on; A/C on. Calculate contaminated runway TOW and maximum abandonment speed.

SOLUTION

From the normal dry runway tables: CAP 698 Page 65
VMCG = 108 KTS
V1 = 131 kts. – 2kts. (2% Down) – 1 kt.
(5 kts. Tail) = 128 kts.
VR = 133 kts.
V2 = 140 kts.

Left Table @ 6000 ft. @ 55,000 kgs. 6mm Tables. CAP 698 Page 72
Weight Reduction - 8400 kgs.V1 Reduction – 8 kts.
Reduced TOW = 46,600 ft. @ 6000 ft.
Right Table @ 6200 ft. @ 6000 ft.
VMCG Limited Maximum TOW = 39,500 kgs.
Maximum Contaminated R/W TOW = 39,500 kgs.
From Normal Tables
V1 = 104 kts. - 2 Kts. (2% Down) – 1 kt. (5kts. Tail) = 101 kts.
VR = 110 kts.
V2 = 122 kts.
Contaminated R/W TOW = 39,500 kgs. Maximum Abandonment Speed = 108 kts.

The Take-off Climb - Class ‘A’ Aeroplanes

The Take-off Climb - Class 'A' Aeroplanes

1. The aeroplane in the worst circumstance arrives at screen height, 35 ft, at the end of the take-off distance required at a speed of V2 with full take-off power set but with the critical power unit inoperative. It has take-off flap set and the undercarriage extended. Before the aeroplane can continue en-route it must have its configuration changed. The flaps and undercarriage must be retracted and the aircraft accelerated to the final en-route climb speed.

2. The transition from the take-off to the en-route configuration and the acceleration to the final segment climb speed must be complete before the aeroplane attains 1500 ft. Net height *[JAR-25.111 (a)]*. The take-off path is determined by a continuous take-off path or by synthesis from segments which relate to distinct changes in configuration, power or thrust, and speed. *[JAR-25.111 (d)]*. Thus the aeroplane must be 'cleaned up' in a manner preordained in JAR's.

3. The regulations specify that whilst the transition is taking place the aircraft must avoid all obstacles that are in the 'obstacle accountability area' by a minimum vertical interval of 35 ft or by the horizontal distance detailed in Figure 15-2. *[JAR-OPS 1.495]*.

4. The flight path determined for the aeroplane therefore commences at the end of the take-off distance required at screen height and is constructed assuming the critical engine to be inoperative *[JAR-25.115(a)]*. The minimum permissible gradient for each segment is specified in JAR-25 and the minimum height of flap retraction is stated in *[JAR-25.111 (c) (4)]* as 400 ft gross. If water injection is used to increase the power developed during take-off it is not to be switched off until 400ft gross height is attain *[ACJ-25.121 (a) (1) and (b) (1)]*.

Take-Off Climb - Regulations

Obstacle Accountability Area. The area immediately beyond the end of TODA (or TODR if turning sooner) is referred to as the obstacle area of accountability. It is sometimes called the obstacle domain or 'funnel'. See Figure 15-1.

Obstacle Clearance. All obstacles in the domain must be cleared by a vertical interval of 35 ft; this is increased to 50 ft if a turn is commenced at a height above 400 ft gross height having a bank angle of between 15° and 25°. See Figure 15-4. Maximum obstacle clearance is obtained at the speed that gives the maximum ratio of ROC to forward speed.

Schedule Turns. Turns may not be made at a height less than 50 ft or half wing span (whichever is the greater) i.e. out of 'ground effect" and may not exceed 15° of bank. Any turns planned above the minimum flap retraction of 400 ft. Gross height may use bank angles up to 25°.

Obstacle Accountability Area Dimensions

(a) Starting Semi-Width = 90 m *[JAR-OPS 1.495 (a)]*.

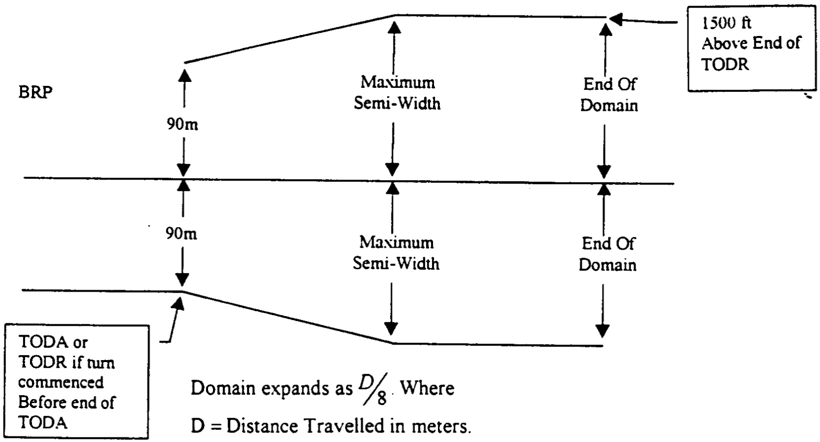
(b) Expansion Rate= D/8 or 0.125 D *[JAR-OPS 1.495 (a)]*.

(c) Maximum Semi-width *[JAR-OPS 1.495 (d) and (e)]*.

(i) Track change 15° or less. 300 m if required navigation accuracy is attained, 600m if not.

(ii) Track change greater than 15° 600m. If required navigational accuracy is attained, 900 m if not. See Figure 15-2.

FIGURE 15-1
The Obstacle Domain for NFP - Class 'A' Aeroplanes



Domain expands as $D/8$. Where

D = Distance Travelled in meters.

FIGURE 15-2
Maximum Obstacle Domain Semi-Width

Maximum Semi-Width of Obstacle Domain *[JAR-OPS 1.495 (d) and (e)*.

Change of Track Direction	0° - 15°	Dist from End of TODA to Max Semi-Width	Over 15°	Dist from End of TODA to Max Semi-Width
Able to maintain required Nav accuracy	300 m	1680 m	600 m	4080 m
All other conditions	600 m	4080 m	900 m	6480 m

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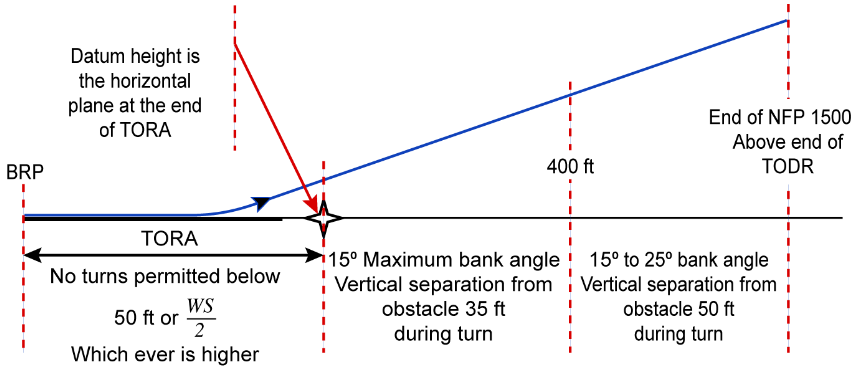
CONTENTS

FIGURE 15-3
Turn Gradient Corrections

Adjustments required to assure adequate stall margin and Gradient Correction		
Bank	Speed	Gradient Correction
15°	V2	1x Aeroplane Flight Manual 15° Gradient Loss
20°	V2 + 5 kts	2 x Aeroplane Flight Manual 15° Gradient Loss
25°	V2 + 10 kts	3 x Aeroplane Flight Manual 15° Gradient Loss

This Table is to be used in the absence of Flight Manual Information. (*AMC-OPS 1.495 (c) (3)*)

FIGURE 15-4
Turns Permitted in NFP - Class 'A' Aeroplanes



Safe Routes. Operators are to produce contingency plans that contain safe emergency escape routes which avoid obstacles and either maintain the en-route requirements or route to a suitable aerodrome of intended landing.

Vertical Clearance of Obstacles. When operating from a dry, runway the net flight path ensures all obstacles within the 'Obstacle Accountability Area' are avoided by a minimum vertical interval of 35 ft; except during turns of greater than 15° of bank it is increased to 50 ft. When take-off is made from a wet or contaminated runway the screen height is reduced to 15 ft. This implies that close-in obstacles may only be avoided by a vertical interval of 15 ft. Great care must be taken if the TOW is obstacle limited. *[IEM-OPS 1. 495 (a) (2)]*.

The Segmented Net Flight Path

See Figure 15-5 and Figure 15-6.

1st Segment. This segment commences at screen height at the end of the take-off distance required at which point the undercarriage 'UP' button is pressed. The speed is V2, free air safety speed, and the power set at maximum take-off power one engine inoperative. The segment ends when the undercarriage is fully retracted and is the start of the second segment.

2nd Segment. The speed and power are maintained until the aeroplane attains flap retraction altitude (minimum 400 ft gross). The segment ends on attainment of this altitude which is the commencement of the third segment. The first and second segments are referred to as the 'Initial Climb'.

3rd Segment. This segment is an acceleration segment, it may be level or still climbing if sufficient power is available. The segment ends when the aeroplane, after flap retraction, achieves the final segment climb speed which signifies the beginning of the 'Final Climb'. The maximum elected height of flap retraction is dependent on the take-off thrust maximum time limit.

4th Segment. This is the final climb. The power setting must be reduced after 5 minutes from the brakes release point, to maximum continuous power setting. The speed is maintained at the final segment climb speed. The net flight path ends at 1500 ft net height.

5th and 6th Segment. Some low powered aeroplanes may require a further two segments to reach 1500 ft and the en-route climb speed.

NOTE:

Some aeroplanes have sufficient power available, in excess of the power required, to retract flap whilst climbing and accelerating, in which case, it is unnecessary to level for the third segment.

FIGURE 15-5
Typical Six Segment Net Flight Path

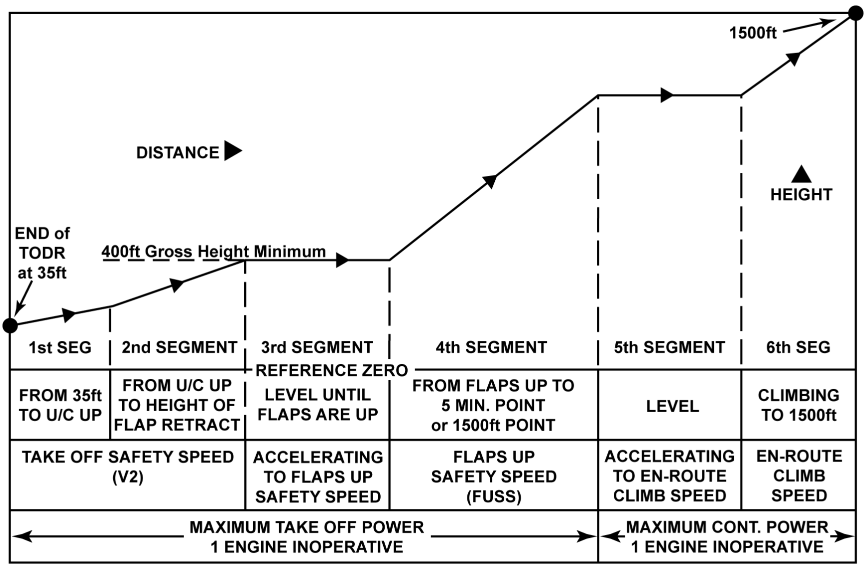
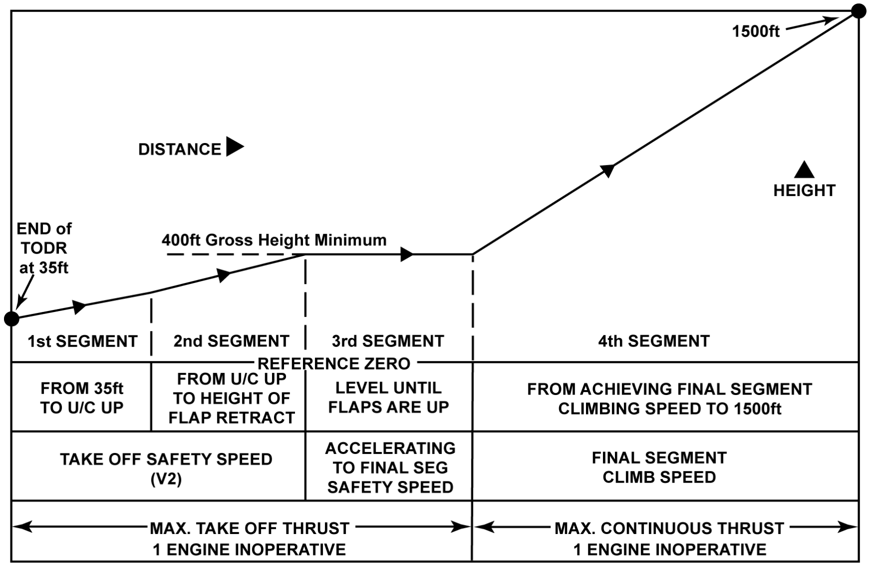


FIGURE 15-6
Typical Four Segment Net Flight Path



Take-Off Climb Performance Requirements

5. The actual path of the average aeroplane flown by the average pilot is the gross flight path. The gradient is reduced in the climb for safety reasons to become the net flight path. Only the net flight path may be used to determine obstacle clearance. *JAR-25.115 (b)* states that the net take-off flight path data is to be the gross take-off flight path reduced by:

(a) 0.8% for Two-Engined Aeroplanes.

(b) 0.9% for Three-Engined Aeroplanes

(c) 1.0 % for Four-Engined Aeroplanes.
See Figure 15-7.

6. The level acceleration segment will be increased in length in the net flight path because the gross acceleration will be reduced by an amount equivalent to the climb gradient diminishment *[JAR-25.115 (c)]*.

7. The minimum acceptable gradients of climb for each segment are specified in *[JAR- 25.121]*. The gradient exigencies of the requirements are true, free-air gradients which are derived from true (pressure) rates of climb without the benefit of ground effect. If the climb path is free of obstacles then attaining the minimum gradient in each segment is the only requirement. This can be achieved by utilizing a relatively simple graph known as the 'WAT LIMIT' (Weight - Altitude - Temperature) graph. See CAP 698 page 57.

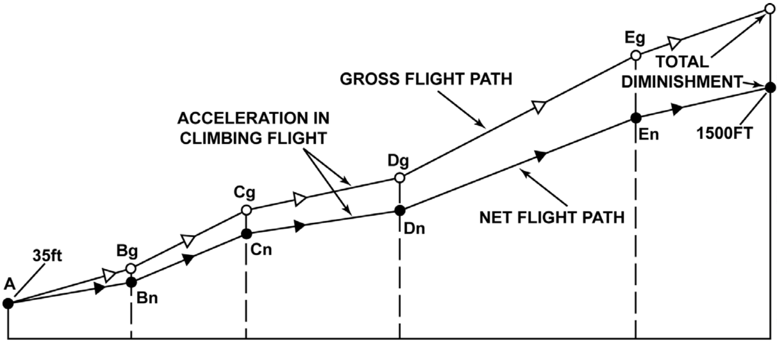
FIGURE 15-7
Climb Path Minimum Gradient Requirements

Number Of Power Units	2		3		4	
GFP Diminishment	0.8%		0.9%		1.0%	
Segment	Gross	Net	Gross	Net	Gross	Net
1st	0%	-0.8%	0.3%	-0.6%	0.5%	-0.5%
2nd	2.4%	1.6%	2.7%	1.8%	3.0%	2.0%
3rd	1.2%	0.4%	1.5%	0.6%	1.7%	0.7%
Final Climb	1.2%	0.4%	1.5%	0.6%	1.7%	0.7%

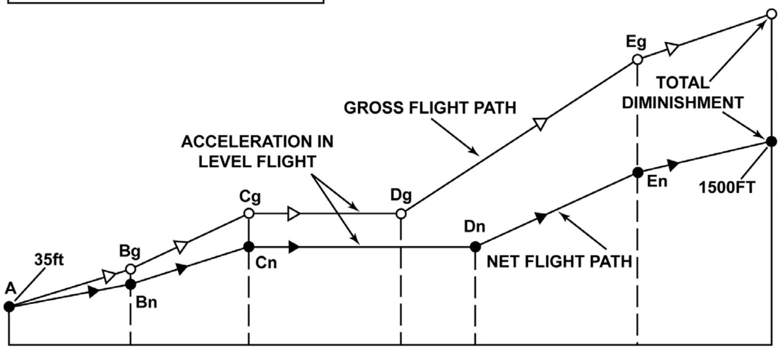
The Relationship of NFP to GFP

8. The length of any climb segment of the NFP is exactly equal to the length of the same segment in the GFP, but the gradient is diminished by the amount specified. If any particular GFP segment is horizontal, the same segment of the NFP is horizontal, and the gross acceleration in level flight is diminished by an acceleration equivalent to the specified gradient margin. In which case the gross fourth segment will be longer than the net fourth segment. The height achieved by the end of each segment of the NFP is also the height at which the next segment commences to form a continuous flight path. See Figure 15-8.

FIGURE 15-8
The Diminishment of the GFP



ACCELERATION IN CLIMBING FLIGHT



ACCELERATION IN LEVEL FLIGHT

The Weight-Altitude Temperature (WAT) Limit

9. Even if there are no significant obstacles in the accountability area, on reaching screen height after take-off the aeroplane must continue to climb at a safe gradient. The minimum climb gradients considered to be acceptable are specified by the JAA and published in detail in the Joint Aviation Requirements (JAR's).

10. The most severe climb gradient requirement is that of the second segment, which for twin-engined Class 'A' aeroplanes is 2.4% gross, 2.7% for three-engined and 3.0% for four-engined aeroplanes. The gradient of this segment is the most demanding and must be attained. The ability of an aeroplane to comply with any gradient requirement is influenced by many factors. If it cannot achieve this minimum gradient, in any particular set of circumstances, then the TOW must be reduced until compliance can be attained.

11. There is, therefore, a specific maximum weight at which the minimum acceptable gradient can be attained for each set of conditions. This weight is commonly referred to as the weight-altitude-temperature (WAT) limit or, as the Americans call it, the 'Take-off Performance Climb Limit'. In JAR's it is referred to as the 'Climb Limited Take-off Mass'.

12. The factors which, either individually or together, adversely affect aeroplane performance and restrict the WAT Limited TOW are:

(a) High Aerodrome Pressure Altitude – causes Low Air Density.

(b) High Aerodrome Surface Temperature – causes Low Air Density.

(c) High Flap Angle – reduces the aeroplane's ability to climb.

(d) Engine Anti-Icing Selected On – reduces the power developed by the engines.

(e) Air Conditioning System Selected On – bleeds air from the engines thus reducing power.

(f) Power Management Computer Selected. Off – reduces engine handling efficiency.

13. The WAT Limited TOW can be determined from a relatively simple graph. In constructing the graph the manufacturers make the following assumptions:

(a) The critical engine fails at V1.

(b) The serviceable engine(s) remain at maximum take-off power.

(c) The aerodrome is maintaining a climbing speed of V2.

(d) The air conditioning system is selected on.

(e) The engine anti-icing system is selected off.

(f) Still air conditions

14. A method of correcting the resultant WAT TOW for the air conditioning system being selected off and/or the engine anti-icing system being selected on is available, if it is not included as a grid within the graph. If the aeroplane is flown in accordance with these assumptions then the WAT TOW limitation guarantees the required minimum gradient will be attained. *JAR-OPS 1.490 (a)* prohibits take-off at a weight in excess of the WAT TOW because the gradient obtained from screen height would be dangerously low.

15. On one occasion only is it permissible to legally exceed the WAT limited TOW and this is when using the 'Increased V2' technique for take-off. With the approval of the JAA, if there is a large excess of the distance available for take-off over that required then it may be utilized to improve TOW above the WAT TOW. This is achieved by holding the aeroplane on the ground so as to accelerate to a higher V2 and to then climb the aeroplane at an 'increased V2' usually referred to as VX. Thus instead of climbing at the minimum safe speed V2 the aeroplane is climbed at the maximum gradient climb speed VX.

16. Most American engines have a 'Flat Rating Cut-Off' which limits the maximum power setting that can be made with the thrust levers. In conditions of high air density it is possible for the engine temperature to exceed the maximum safe limitation if the thrust is not restricted. This limitation is often imposed by a power management computer (PMC) automatically but if it is not being used then a manual correction has to be made to the WAT limited TOW determined from the graph.

17. Compliance with the WAT limited TOW only guarantees attainment of the most severe gradient requirement of the take-off flight path. It does NOT guarantee safe clearance of any obstacles in the area of accountability.

The Take-Off Performance Climb Limit Graph

18. The specimen aeroplane used for examination purposes uses CAP 698 page 57 which is titled 'Take-Off Performance Climb Limit'.

19. It is basically a grid based on atmospheric air density and has a grid to enable to be used with either of the two take-off flap settings 5° or 15°. Correction statements are given below the main grid to allow for air conditioning packs, engine anti-icing and the non-use of the power management computer.

20. The main grid has a kink which is the 'Flat-Rating Cut-Off' at ISA +15°C and a line which is the 'environmental limit' at ISA + 39.5°C. The aeroplane should never be operated at combinations of pressure altitude and ambient temperature which position the density below the environmental limit line on the graph.

21. A line titled 'Assumed Temperature Limit' confines the assumed temperature for variable thrust calculations to the area in the main grid above the line. Although the assumed temperature used for variable thrust calculations may fall between the environmental limit line and the assumed temperature limit line this is permissible because it will be used for calculation purposes only to determine the limiting operational parameter **not** to actually operate the aeroplane.

WAT Limited TOW Calculation Procedure

(a) Enter the carpet of the graph at the ambient OAT.

(b) Proceed vertically to intersect the aerodrome pressure altitude in the grid.

(c) From this intersection move horizontally left to the flap angle reference line.

(d) If flap setting is 5° continue horizontally left to read the WAT limited TOW. If the flap is set to 15° then from the reference line parallel the grid lines to the left vertical axis to read the WAT limited TOW.

EXAMPLE 15-1

EXAMPLE

Given: Aerodrome Pressure Altitude 2000 ft; Ambient Temperature + 33°C; Flap Setting 15°. Calculate the WAT TOW.

SOLUTION

53,400 kgs.

EXAMPLE 15-2

EXAMPLE

Given: As for 15-1 except flap setting 5°. Calculate WAT TOW.

SOLUTION

57,600 kgs. Comparison with Answer 15-1 shows that the aeroplane climbs more efficiently at the lower flap setting.

EXAMPLE 15-3

EXAMPLE

Given: Aeroplane Pressure Altitude 6000ft; Ambient temperature + 33°C; Flap Setting 15°. Calculate WAT TOW.

SOLUTION

46,200 kgs. Comparison with Answer 15-1. Shows that the aeroplane is less efficient in the rarer atmosphere causing the WAT TOW to be reduced considerably.

EXAMPLE 15-4

EXAMPLE

Given: Aeroplane Pressure Altitude 7000 ft; Ambient temperature +20°C; Flap setting 15°; ACS packs off.

SOLUTION

48,800 kgs. + 900 kgs. For ACS Off = 49,700 kgs.

EXAMPLE 15-5

EXAMPLE

Given: Aerodrome pressure altitude 5000 ft; Flaps 15° set; ACS packs off; TOW 51,000 kgs. Calculate the maximum temperature acceptable.

SOLUTION

Equivalent TOW with ACS packs on = 51,000 – 900 kgs = 50,100 kgs.

Enter left vertical axis at 50,100 kgs. Parallel the grid lines to the flap reference line. Travel horizontally right to 5000 ft. Pressure altitude. Drop vertically to the carpet of the graph to read + 28°C

The Effect of Sloping Runway

22. *JAR–OPS 1.495 (a)* requires Class 'A' aeroplanes to clear all obstacles in the accountability area by a vertical interval of 35 ft. This means that the net flight path which commences at screen height at the end of TODR must clear the obstacles by a minimum of 35 ft. However, obstacle details published in the AIP are related to the brakes release point with regard to distance. The elevation is quoted above mean sea level. It is therefore, essential to relate the obstacle to the commencement of the NFP. It the runway is level, this simply requires the TODR to be subtracted from the quoted obstacle distance before commencing calculation.

23. If the runway is sloping due allowance must be made for the difference in elevation between the brakes release point and the elevation of the horizontal plane at the end of TODR. This plane is known as 'reference zero'. The maximum slope of a runway for use by Class 'A' aeroplanes should not exceed 2%, however the JAA my permit specific runways with a greater slope to be used with special authorization.

24. The correction that must be made to the obstacle elevation to relate it to reference zero may be calculated by determining the elevation at the end of TODR i.e. the elevation of reference zero and subtracting it from the obstacle elevation.

Elevation at end of TODR = Elevation of BRP ± (TODR x R/W Slope x 3.28) when TODR is in M.

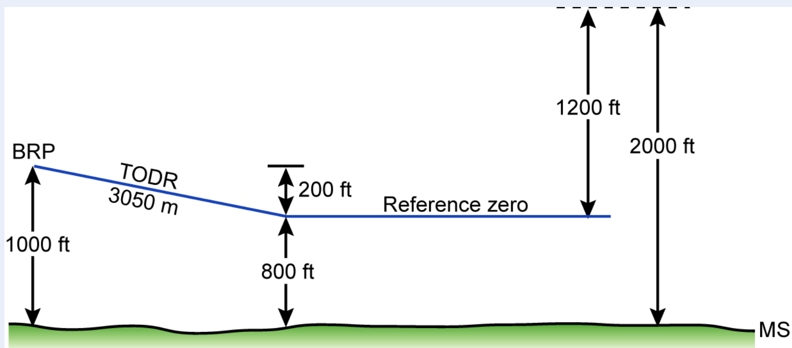
EXAMPLE 15-6

EXAMPLE

Given: BRP 1000 ft AMSL; R/W Slope 2% Down; TODR 3050 m; Obstacle Elevation 2000 ft AMSL. Calculate obstacle height above reference zero.

SOLUTION

Elevation at end of TODR = 1000 ft – (3050 x .02 x 3.28) = 800 ft. Obstacle Height = 2000 – 800 = 1200 ft above R2.



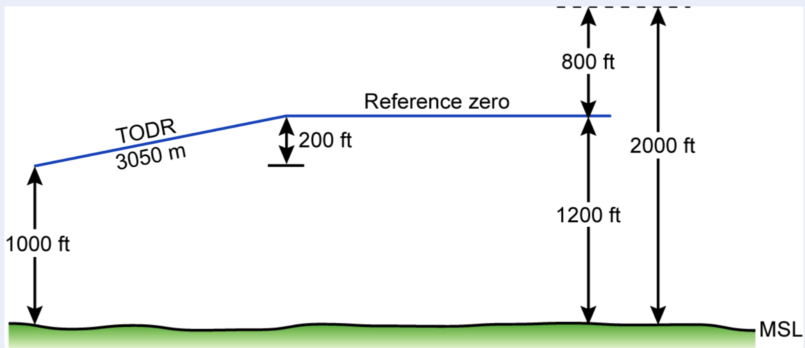
EXAMPLE 15-7

EXAMPLE

Given: BRP 1000 ft amsl; R/W Slope 2% up; TODR 3050m; Obstacle elevation 2000 ft. amsl. Calculate obstacle height above reference zero.

SOLUTION

Elevation at end of TODR = 1000 ft + (3050 x 2% x 3.28) = 1200 ft. Height of obstacle above RZ = 2000 – 1200 = 800 ft



25. From these two examples it can be seen that the elevation at the end of TODR is the elevation of the BRP decreased by a downslope adjustment or increased by an upslope adjustment. The obstacles height above reference zero is the obstacle elevation AMSL m**inus** end TODR elevation AMSL.

Obstacle Limited TOW Calculation

26. To calculate the obstacle limited TOW it is first necessary to adjust the obstacle details and relate it to the end of TODR and reference zero. Having done this the corrected details are used in a graph titled 'Take-Off Performance Obstacle Limits' which are CAP 698 pages 82 and 83. The assumptions made by the manufacturers in the construction of these graphs were:

(a) The aeroplane suffers a failure of the critical engine at V1.

(b) The remaining live engine(s) continue with maximum take-off power set.

(c) The aeroplane is climbed at V2 speed.

(d) The ambient temperature is +30°C (ISA +15°C) at an aerodrome pressure altitude of MSL in still air.

27. Any difference between the DATUM conditions in Paragraph Paragraph 26 above and the ambient conditions is allowed for by the use of correction grids within the graph. The wind grid is already biased for safety allowing on 50% of any headwind and 150% for any tailwind. Separate graphs are provided for each take-off flap setting. To use the graph to calculate the obstacle limited TOW:

(a) Enter the lower left axis at the corrected obstacle height and move horizontally right to intersect the corrected obstacle distance.

(b) From this point travel vertically up to the temperature grid reference line. Parallel the grid lines to intersect an input at the aerodrome surface ambient temperature.

(c) Continue vertically from this point to the aerodrome pressure altitude reference line. Now parallel the grid lines to intersect an input at the pressure altitude of reference zero.

(d) Move vertically from this intersection to the wind component reference line then parallel the grid lines to intersect the appropriate wind component.

(e) From this final intersection move vertically to the horizontal axis at the ceiling of the graph to read the obstacle limited TOW.

EXAMPLE 15-8

EXAMPLE

Given: BRP elevation 1200 ft AMSL; TODR 5000 ft; R/W Slope 2% up; Wind Component 20 kts. Head; Flaps 5° Ambient Temp. + 37°C; Obstacle Elevation 1660 ft amsl; Obstacle Distance from BRP 18,000 ft; QNH 1023 mbs.

Calculate the Obstacle Limited TOW with PMC on.

SOLUTION

Elevation of RZ = BRP elevation + (TODR x R/W SLOPE) = 1200 ft + (5000 x 2%) = 1300 ft.

Pressure Altitude of RZ = Elevation + [(1013 – 1023) x 30] = 1300 – 300 = 1000 ft.

Obstacle Height Above RZ = Obstacle Elevation Minus RZ Elevation = 1660 – 1300 = 360 ft.

Obstacle Distance From BRP = 18,000 ft

MRJT 1 page 40. 5° flap take-off performance obstacle limits graph.

Enter lower left vertical axis at 360 ft.

Move horizontally right to intersect 18000 ft obstacle distance from BRP. Travel vertically to OAT reference line than parallel the grid lines to +37°C. From this point continue vertically to the pressure altitude reference line then parallel the grid lines to 1000 ft. Now continue vertically to the wind component reference line then parallel the grid lines to 20 kts. Head Component. Move vertically to read the obstacle limited TOW 51, 700 kgs.

EXAMPLE 15-9

EXAMPLE

Details as for Example 11-8 except flaps 15°.

SOLUTION

49,400 kgs.

A comparison of the two answers shows that obstacle clearance is more difficult to attain at the higher flap setting which requires the TOW to be reduced by 2,300 kgs.

EXAMPLE 15-10

EXAMPLE

Given: BRP elevation 1000 ft; TODR 4000 ft; R/W Slope 2% down. Wind Component 10 kts head; Ambient Temp + 20°C; QNH 1003 mbs; PMC off; Flaps 5°; Obstacle Elevation 1620 ft; Obstacle Distance from BRP 22000 ft.

Calculate the Obstacle Limited TOW.

SOLUTION

Elevation of RZ = 1000ft - (4000 x 2%) = 920 ft. Pressure Altitude of RZ = 920 +[(1013 – 1003) x 30] =1220 ft. Obstacle Height above RZ = 1620 – 920 = 700 ft. Obstacle Distance from BRP = 22000 ft. From Graph – Obstacle Limited TOW = 49,900 kgs PMC off correction = -4, 970 kgs Obstacle Limited TOW = 44,930 kgs

EXAMPLE 15-11

EXAMPLE

Details as for Example 11-10 except flaps 15°.

SOLUTION

Obstacle Limited TOW = 47,700 kgs – 4970 kgs = 42,730 kgs.

EXAMPLE 15-12

EXAMPLE

Given: BRP Elevation 1000 ft amsl; TODR 5000 ft; R/W Slope 2% Up; Wind Component 5 kts tail; Ambient Temperature + 15°C; QNH 983 mbs; PMC On; Flaps 5°; Obstacle Elevation 17000 ft amsl; Obstacle Distance from BRP 28000 ft.

Calculate the Obstacle Limited TOW.

SOLUTION

Elevation of RZ = 1000 ft + (5000 x 2 %) = 1100 ft Pressure altitude of RZ = 1100 + [(1013 – 983) x 30] = 2000 ft. Obstacle Height Above RZ = 1700 – 1100 = 600 ft. Obstacle Distance From BRP = 28000ft. From Graph – Obstacle Limited TOW = 52,100 kgs.

EXAMPLE 15-13

EXAMPLE

Details as for Example 11-12 except flaps 15°.

SOLUTION

Obstacle Limited TOW = 49,500 kgs

Self Assessed Exercise No. 2

QUESTIONS:

QUESTION 1.

For a segmented net flight path what determines the beginning and end of a segment?

QUESTION 2.

What is the minimum vertical interval that an aeroplane must avoid all obstacles in the flight path obstacle accountability area?

QUESTION 3.

State the restrictions imposed on the angle of bank that may be used for scheduled turns in the net flight path.

QUESTION 4.

Specify the maximum semi-width of the obstacle accountability area and the distance from the end of TODA at which it is attained for a change of track direction of 20× if the required tracking accuracy can be maintained.

QUESTION 5.

What speed should be flown to provide an adequate stall margin during a turn using 20° of bank?

QUESTION 6.

What speed and power should be maintained during the first and second segments of the net flight path?

QUESTION 7.

What is the minimum height of flap retraction?

QUESTION 8.

What determines the end of the net flight path?

QUESTION 9.

What diminishment is applied to the gross flight path to determine the net flight path for a twin-engined aeroplane.

QUESTION 10.

Define VX.

QUESTION 11.

What guarantee is provided by the WAT limit graph?

QUESTION 12.

List the factors that adversely affect the WAT limited TOW.

QUESTION 13.

When may the WAT limited TOW be exceeded?

QUESTION 14.

Define "flat rating cut-off".

QUESTION 15.

How does the flap setting affect the WAT limited TOW?

QUESTION 16.

Given: Aerodrome pressure altitude 4000ft. Ambient Temperature +40°C. ACS on. PMC on. Anti-ice off. 15° flap. Determine the climb limited TOW for an MRJT?

QUESTION 17.

Given: BRP 3420ft amsl; Runway slope 1.3% downhill; TODR 2760m; Obstacle elevation 3785ft. Calculate the obstacle height above reference zero.

QUESTION 18.

List the factors assumed by the manufacturers in the construction of figures 4.20 and 4.21 of CAP 698.

QUESTION 19.

Given: Reference Zero 2000ft amsl; Wind component 4kts tail; Ambient temperature +20°C; Flaps 5°; Obstacle elevation 2400ft; Obstacle distance 5500m from BRP. PMC on. Calculate the obstacle limited TOW.

QUESTION 20.

Given: Reference Zero 2000ft amsl; Wind component 4kts tail; Ambient temperature +20°C; Flaps 15°; Obstacle elevation 2400ft; Obstacle distance 5500m from BRP. PMC on. Calculate the obstacle limited TOW.

ANSWERS:

ANSWER 1.

Page 15-1 Paragraph 2

ANSWER 2.

Page 15-2 Paragraph 4

ANSWER 3.

Page 15-2 & 15-3 Paragraph 4

ANSWER 4.

Page 15-3 Figure 15-2

ANSWER 5.

Page 15-3 Figure 15-3

ANSWER 6.

Page 15-5 Figure 15-5

ANSWER 7.

Page 15-5 Figure 15-5

ANSWER 8.

Page 15-5 Figure 15-6

ANSWER 9.

Page 15-6 Paragraph 5

ANSWER 10.

Page 15-9 Paragraph 15

Page 15-9 Paragraph 17

ANSWER 11.

Page 15-8 Paragraph 12

ANSWER 12.

Page 15-9 Paragraph 15

ANSWER 13.

Page 15-9 Paragraph 16

ANSWER 14.

Page 15-8 Paragraph 12

ANSWER 15.

CAP 698 page 57 47200kgs

ANSWER 16.

$$\text{Height difference} = 2760 \times \frac{1.3}{100} \times 3.28\text{ft} = 117.7\text{ft}$$

Elevation of end of TODR = 3420 - 117.7 = 3302.3ft

Obstacle height above RZ = 3785 - 3302.3 = 482.7ft

Page 15-12 Example 15-6

ANSWER 17.

Page 15-13 Paragraph 26

ANSWER 18.

Obstacle distance 5500 x 3.28 = 18040ft

Obstacle limited TOW 50,000kgs

Page 15-15 Example 15-8. Figure 4.20 CAP 698

ANSWER 19.

Obstacle limited TOW 48400kgs

En-Route - Class 'A' Aeroplanes

En-Route Regulations

En-Route - Class 'A' Aeroplanes

En-Route Regulations

En-Route Obstacle Accountability Area

1. The area within which obstacles must be avoided by at least the required minimum vertical interval is contained within 5 nm either side of the planned track or planned route to an alternative aerodrome. This semi-width is increased to 10 nm, if navigational accuracy does not meet the 95% containment level. *[JAR-OPS 1.500 (d) and JAR OPS 1.505 (b)]*

One Engine Inoperative Requirements

2. In the event of one engine becoming inoperative:

   (a) The net flight path must have a positive gradient at 1500 ft. above the aerodrome where the landing is assumed to be made. *[JAR-OPS 1.500 (a)]*.

   (b) The Net flight path must have a positive gradient at 1000 ft. above all terrain and obstructions in the obstacle accountability area. *[JAR-OPS 1.500 (b)]*.

   (c) The drift-down path from the cruising altitude to the aerodrome of intended landing clears all terrain and obstacle by a minimum vertical interval of 2000 ft *[JAR-OPS 1.500 (c)]*.

Two Engines Inoperative Requirements

3. If the route extends beyond a distance of 90 minutes at the all-engines long range cruising speed at standard temperature, in still air, from a suitable landing aerodrome then the aeroplane must be capable of complying with the following criteria with two engines inoperative:

(a) The net flight path must have a positive gradient at 1500 ft. Above the aerodrome where the landing is assumed to be made. *[JAR-OPS 1.505(d)]*.

(b) The net flight path from cruising altitude to the aerodrome of intended landing clears all terrain and obstacles by a minimum vertical interval of 2000 ft. *[JAR-OPS 1.505 (b)]*.

4. If the aeroplane is unable to comply with these regulations, then this imposes a route restriction on the aeroplane. It, therefore, is a permanent route restriction on twin-engined aircraft not being operated under ETOPS Regulations in CAP 513.

5. In assessing the ability of the aeroplane to comply with either the one engine or two engines inoperative the following assumptions are made:

(a) The engine(s) fail at the most critical point along the route. In the case of two engines inoperative a simultaneous failure is assumed at the most critical point of the portion of the route beyond the 90-minute point.

(b) Fuel jettisoning is permitted to an extent consistent with reaching the aerodrome of intended landing with:

(i) The required reserves with one engine inoperative.

(ii) The required reserves plus 15 minutes level flight at 1500 ft. overhead the aerodrome with two engines inoperative.

(c) The aerodrome of intended landing is large enough and has the facilities to cope with the aeroplane. Additionally the weather reports and forecasts, together with the surface condition must be such that a safe landing can be accomplished at the estimated time of landing.

(d) The effect of the wind and the use of the ice protection system are accounted in the calculation of the descent path.

Gross Flight Path Diminishment

6. To determine the net drift-down gradient the gross gradient must be diminished by the appropriate amount from the following table:

FIGURE 16-1
Gross Gradient Diminishment

A/C Type	One Engine Inoperative	Two engines inoperative
Twin Engined	-1.1%	-
Three Engined	-1.4%	-0.3%
Four Engined	-1.6%	-0.5%

Descent Path Determination

7. In flight, having suffered an engine failure, the immediate actions are:

(a) Complete the emergency drills.

(b) Maintain a level attitude, set maximum continuous limit % N1 on the remaining engine.

(c) Wait for the speed to decay to the en-route climb speed one engine inoperative. This is referred to as the optimum drift-down speed which should revised for the changing weight and pressure altitude during the descent.

(d) Determine your intentions. (i.e. continue, return or divert).

(e) Having determined the reason for the failure. Attempt to relight the failed engine at the maximum relight altitude, if permissible.

(f) If the relight is unsuccessful or is not permissible continue to drift-down to stabilising altitude, when level target the one-engine inoperative long-range cruise speed.

Ceilings and Stabilising Altitudes

8. A **ceiling** is the pressure altitude at which a 0% gradient of climb is attained with **all engines operating.** There are three ceilings:

(a) **Absolute Ceiling.** The pressure altitude at which a gross rate of climb of 0 fpm is attained.

(b) **Gross Ceiling.** The pressure altitude at which a gross rate of climb of 500 fpm is attained for jet-engined aeroplanes (100 fpm for piston engined aircraft). It is the maximum practical pressure altitude to operate an aeroplane and is often referred to as the 'service ceiling'.

(c) **Net Ceiling.** The pressure altitude at which a gross rate of climb of 750 fpm is attained for jet-engined aeroplanes (150 fpm for piston engined aircraft).

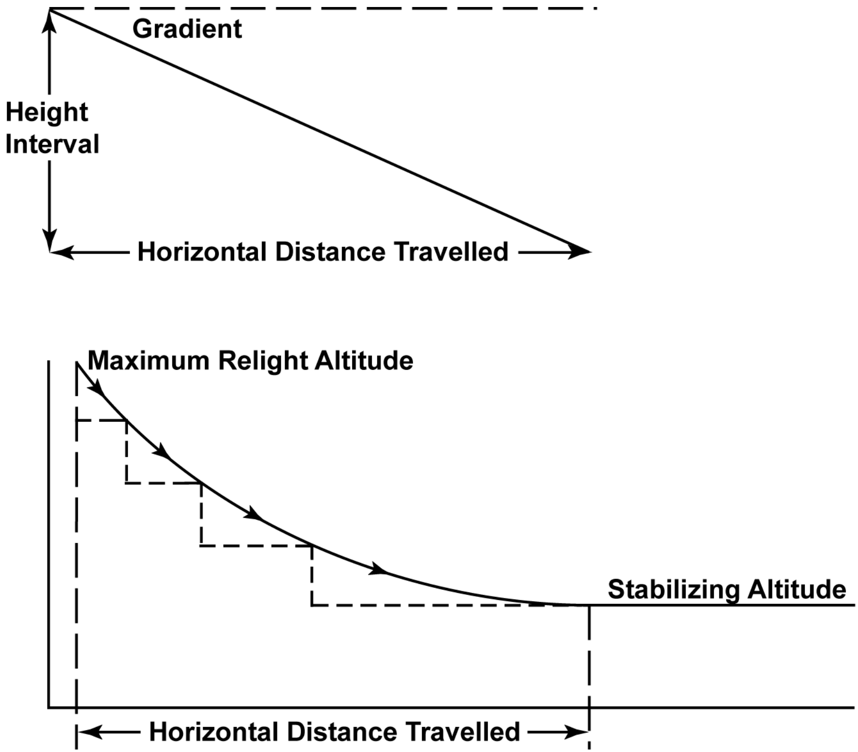
9. A **stabilising altitude** is the pressure altitude at which a 0% gradient of climb is attained with **one (or two) engines inoperative.** There are three stabilising altitudes:

(a) **Absolute Stabilising Altitude.** The pressure altitude at which a gross rate of climb of 0 fpm is attained. It is the pressure altitude at which the best performance of an aeroplane with one engine inoperative will cease to drift down.

(b) **Gross Stabilising Altitude.** The pressure altitude at which a gross rate of climb of 500 fpm is attained. It is the assumed pressure altitude at which an average aeroplane of the type will cease to drift-down.

(c) **Net Stabilising Altitude.** The pressure altitude at which a gross rate of climb of 750 fpm. is attained. It is the pressure altitude that must be used for comparison with the terrain profile to ensure compliance with the operating regulations contained in **JAR-OPS 1.500 and AMC-OPS 1.500.**

FIGURE 16-2
Drift-Down Profile



Segment Drift-Down Path

10. The ground distance travelled in each segment is calculated in n.mls by the formula

$$\frac{\text{Height Interval}}{\text{Mean Gradient}} \times \frac{100}{6080} \times \frac{G/S}{TAS}$$

The mean gradient for the segment is that at the mid-altitude for the AUW and temperature at that altitude.

The Calculation of the Drift-Down Path [AMC-OPS 1.500]

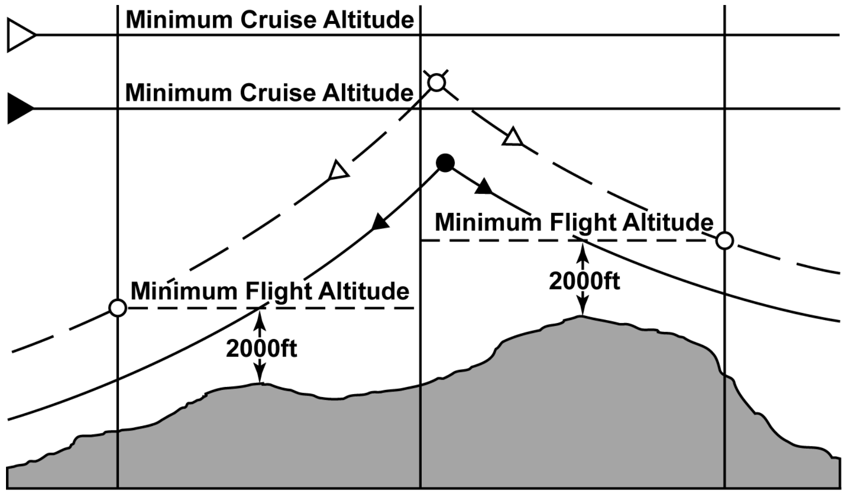
(a) The high terrain or obstacle analysis required for showing compliance with JAR-OPS 1.500 may be carried out in one of two ways, as explained in the following three paragraphs.

(b) A detailed analysis of the route should be made using contour maps of the high terrain and plotting the highest points within the prescribed corridor's **width** along the route. The next step is to determine whether it is possible to maintain level flight with one engine inoperative 1000 ft above the highest point of the crossing. If this is not possible, or if the associated weight penalties are unacceptable, a Drift-Down procedure should be worked out, based on engine failure at the most critical point and clearing critical obstacles during the Drift-Down by a least 2000 ft. The minimum cruise altitude is determined by the intersection of the two drift-down paths, taking into account allowances for decision making (see Figure 16-3). This method is time consuming and requires the availability of detailed terrain maps.

(c) Alternatively, the published minimum flight altitudes (Minimum En route Altitude, MEA, or Minimum Off Route Altitude, MORA) may be used for determining whether one engine inoperative level flight is feasible at the minimum flight altitude or if it is necessary to use the published minimum flight altitudes as the basis for the drift-down construction (see Figure 16-3). This procedure avoids a detailed high terrain contour analysis but may be more penalising than taking the actual terrain profile into account as in paragraph b.

(d) In order to comply with JAR-OPS 1.500 (c), one means of compliance is the use of a MORA and, with JAR-OPS 1.500 (d), MEA provided that the aeroplane meets the navigational equipment standard assumed in the definition of MEA.

FIGURE 16-3
The Determination of Minimum Cruise Altitude



NOTE:

MEA or MORA normally provide the required 2000 ft obstacle clearance for drift-down. However, at and below 6000 ft altitude, MEA and MORA cannot be used directly as only 1000 ft clearance is ensured.

There are two methods that can be utilised to determine the drift-down paths described above:

Method A

(a) Determine the minimum en-route altitude (MEA) or minimum off route altitude (MORA) as appropriate for the route.

(b) Calculate the one-engine inoperative stabilising weight at this altitude. This then becomes a limitation on the maximum TOW.

(c) If the penalty on TOW is unacceptable then Method B must be used.

Stabilising Altitude Calculations

11. The graph provided for the purpose of stabilising altitude calculations is MRJT 1 page 85 and is titled 'Net Level Off Altitude'. It is a simple straight line graph of net level off pressure altitude against aeroplane gross weight for temperature deviations of ISA + 20°C and below. The change from the air conditioning being 'On' in the auto mode to 'Off' is shown at a pressure altitude of 17000 ft. by a break in the graph lines. If it remains 'On' below this altitude a correction to the graphical value can be made form the table below. Correction can also be made for anti ice bleeds being 'On' for the engines, or for the engines and the wings, from the same table.

12. In the event that one engine becomes inoperative **JAR-OPS 1.500 (b)** requires the aeroplane to have a positive gradient 1000 ft. above all terrain and obstructions within the obstacle accountability area. In other words it must not be descending on reaching the obstacle. The aeroplane must be at the **net** stabilising pressure altitude overhead the obstacle.

EXAMPLE 16-1

EXAMPLE

Given: Obstacle Pressure Altitude 10,000 ft; Ambient Temperature ISA + 20°C; Engine and Wing Anti-Ice on; Air conditioning Auto; Calculate the maximum AUW at which the aeroplane will stabilise to ensure the statutory minimum clearance is obtained.

SOLUTION

Pressure Altitude Minimum Required 10,000 + 1000 = 11,000 ft.

AUW from graph = 59,800 kgs.
Anti-ice Correction = 5,650 kgs.
Air Conditioning Correction = 2,500 kgs
Maximum AUW = 59800 – 5650-2500 = 51,650 kgs.

EXAMPLE 16-2

EXAMPLE

Given: AUW 55,000 kgs, Engine Anti-Ice On;
Air Conditioning On; ISA Deviation 0°C;
Calculate the Stabilising Pressure Altitude.

SOLUTION

Equivalent AUW = 55000 kgs + 1950 kgs (Engine A/1) +2500 kgs (A/C on) = 59,450 kgs

Stabilising Pressure Altitude = 14,000 ft.

EXAMPLE 16-3

EXAMPLE

Given: AUW 45,000 kgs; ISA Deviation + 15°C;
Engine A/I On; Air Conditioning On:
Calculate the stabilising pressure altitude.

SOLUTION

Equivalent AUW = 45,000 kgs + 1950 kgs (Engine A/I) = 46,950 kgs

Stabilising Pressure Altitude = 19,200 ft

EXAMPLE 16-4

EXAMPLE

Given: Obstacle Pressure Altitude 16000 ft;
ISA Deviation + 15°C; Air Conditioning On;
Engine and Wing Anti-Icing On. Calculate the maximum AUW that will ensure stabilisation at the Statutory minimum clearance above the obstacle.

SOLUTION

Statutory Minimum Pressure Altitude = 17000 ft.
Uncorrected AUW = 51,050 kgs
A/I Correction = - 5,650 kgs.
Corrected AUW = 45,400 kgs.

EXAMPLE 16-5

EXAMPLE

Calculate the maximum temperature at which the aeroplane will stabilise at an AUW or 56000 kgs. At a pressure altitude of 10,000 ft with engine and wing anti-icing equipment on and air conditioning on.

SOLUTION

Equivalent AUW = 56000 kgs + 5650 kgs (A/I on) + 2500 kgs.
(A/C on) = 64,150 kgs. Temperature Deviation = ISA + 17°C.
ISA +17°C = Ambient – [+15 – (2 x 10)] + 12°C = Ambient.

Method B

(a) Using a route profile chart plot the highest points within the obstacle accountability area.

(b) Determine the weight that with one-engine inoperative will enable the aeroplane to stabilise 1000 ft above the highest terrain or obstruction.

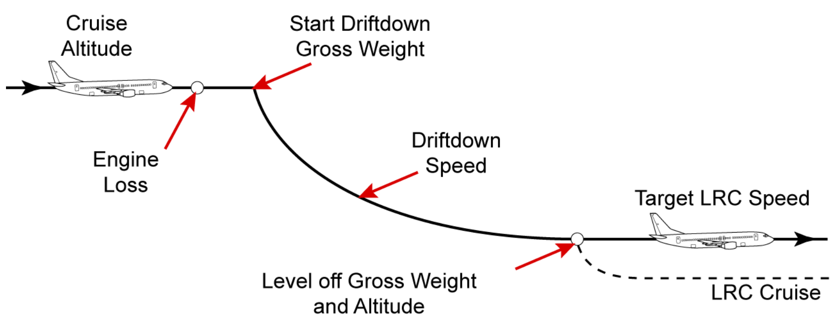
(c) To this stabilising weight add the weight of the fuel that would be used in the drift-down and in the cruise to the assumed point of engine failure i.e. back plot the drift down from 1000 ft above the highest point to determine the worst position of the engine failure.

NOTE:

If an engine failure occurs before this point is reached then although the stabilising altitude will initially be lower the fuel burn to the obstacle will be higher resulting in a lower weight.

(d) If the weight penalty is unacceptable then a drift-down should be calculated from the most critical point along track which avoids the critical obstacle by 2000 ft during the drift-down. The minimum cruising altitude is determined by the intersection of two such paths.

FIGURE 16-4
Drift-Down Profile MRJT



Obstacle Avoidance During Drift-Down Calculations

13. The charts provided in the Performance Manual is CAP 698 pages 86 to 89 for the purpose of drift-down path calculations are all with the air conditioning set to auto high. They are presented for a range of cruising pressure altitudes and are titled 'Drift-Down Profiles Net Flight Path' the altitudes are:

(a) For 37,000 ft. - Page 86

(b) From 33, 000 ft to 35, 000 ft. - Page 87

(c) From 29,000 ft to 31, 000 ft. - Page 88

(d) From 25,000 ft to 27,000 ft. - Page 89

14. These charts facilitate the determination of the following data given the cruising pressure altitude, the gross weight at the time of engine failure and the wind component:

(a) The fuel used in the descent.

(b) The time taken to descend from the engine failure point.

(c) The ground distance from the engine failure point in nm.

15. Before entering the main graph the gross weight at the engine failure point must be corrected for the configuration of the anti-icing and air conditioning systems and then converted to an equivalent gross weight at ISA Deviation 10°C, using the sub-graph above the main graph. The reference line for the sub-graph is ISA 10°C if temperature deviation is above 10°C follow the grid-line to the appropriate value then travel horizontally to determine the equivalent gross weight.

16. To calculate the distance travelled during the descent to a particular pressure altitude adopt the following procedure in the main graph:

(a) Enter the left vertical axis at the required pressure altitude travel horizontally right to the appropriate equivalent gross weight. At this point interpolate between the diagonal broken line to read the fuel used from the engine failure point.

(b) From this intersection drop vertically to the carpet of the main graph to read the time taken to descend.

(c) Continue vertically down to the reference-line of the wind component grid. Parallel the grid lines from this point to the appropriate wind component input. At this intersection drop a vertical to the carpet to read the ground distance travelled in the descent.

EXAMPLE 16-6

EXAMPLE

Given: Cruise Pressure Altitude 37,000 ft; Gross weight at engine failure point 44, 000 kgs; ISA Deviation + 15°C; Anti-icing off; Air Conditioning On Below 17,000 ft; Wind Component 50 kts. Head. Obstacle Pressure Altitude 22, 800 ft.

Calculate the greatest distance from the obstacle at which the aeroplane after suffering an engine failure would clear the obstacle by the statutory minimum during the drift-down, also the fuel used and time taken to reach this point.

SOLUTION

No weight corrections are required. Enter left vertical axis of the sub-graph at 44,000 kgs. Parallel the grid-lines to ISA + 15°C. Now move horizontally right to the sub-graph right vertical axis. Read the equivalent gross weight as 45000 kgs.

Enter the left axis of the main graph at (22,800 + 2000) ft. i.e. 24,800 ft pressure altitude. Move horizontally right to intercept the equivalent gross weight curve of 45,000 kgs. Read the fuel used as 800 kgs. Now drop vertically to the carpet to read the time taken as 27.5 minutes. Continue vertically to the wind reference line and then parallel the grid lines to 50kts. Headwind input. Drop vertically to the carpet to read 128 nm.

EXAMPLE 16-7

EXAMPLE

Given: Cruise Pressure Altitude 30,000 ft; Gross Weight at Engine Failure Point 54, 000 kgs; ISA Deviation + 18°C; Obstacle Pressure Altitude 14000 ft; Wind component 30 kts tail; Engine and Wing Anti-icing On; Air Conditioning Off below 17000 ft. Calculate the maximum distance from the obstacle at which the one engine inoperative drift-down path will clear the obstacle by the statutory minimum, also the fuel used and time taken to reach this point.

SOLUTION

Gross Weight 54,000 kgs + 5,650 kgs. (Eng & Wing A/I) – 1750 kgs. (A/C Off) = Gross Weight 57,900 kgs.

Using the sub-graph at ISA + 18°C the Equivalent Gross Weight = 61,500 kgs. Enter main graph at 16,000 ft pressure altitude @ 61,500 kgs. Read 900 kgs. as fuel used. Drop vertically to read 26 minutes time taken and using 30kts. Tailwind determine the ground distance as 152 nm.

EXAMPLE 16-8

EXAMPLE

Given: Cruise Pressure Altitude 34,000 ft; Obstacle Pressure Altitude 18000 ft; Obstacle Distance From engine failure point 160 nm; Wind Component 50 kts. Head; Engine A/I on; A/C on below 17,000 ft. ISA Deviation +20°C. Calculate the maximum gross weight at the point of engine failure, also the time taken and fuel used in the descent.

SOLUTION

Equivalent Gross WT. 54,000 kgs. Fuel Used 833 kgs.
Gross Weight @ ISA + 20°C = 51,750 kgs.
Engine Anti-Icing On = 5650 kgs.
Gross Weight = 46,100 kgs.
Time Taken = 26 minutes.

EXAMPLE 16-9

EXAMPLE

Given: Cruise Pressure Altitude 31,000 ft; ISA Deviation + 15°C; Wind Component 50 kts. Tail; Obstacle Distance from Engine Failure Point 250 nm; Engine and Wing A/I on; Air Conditioning Off below 17000 ft; Calculate net height at the obstacle and the fuel used and time taken to reach the obstacle if the gross weight at engine failure is 51,000 kgs.

SOLUTION

Corrected Gross Weight = 51,000 + 5,650 – 1,750 = 54,900 kgs. Equivalent Gross Weight = 56,250 kgs.

Time Taken = 40.5 mins.

Fuel Used = 1,500 kgs

Pressure Altitude = 16,800 ft.

Landing - Class 'A' Aeroplanes

The Field-Length Requirements

Landing - Class 'A' Aeroplanes

1. There are two requirements that must be observed when making landing calculations. The first is the Weight-Altitude-Temperature limitation on landing weight and the second the Field–Length Limit on landing weight.

The WAT Limit

2. The limitation imposed on landing weight by virtue of the altitude and temperature is to ensure that in the go-round configuration, that is with the critical engine inoperative and maximum take-off power set on the remaining engine(s) with the undercarriage retracted, the aeroplane is capable of attaining the minimum acceptable gross gradient of climb. That is 2.1% for twin-engined aeroplanes, 2.4% for three-engined aeroplanes and 2.7% for four-engined aeroplanes. *[JAR-25.121(d)]*. In an emergency, fuel jettisoning may be used to attain the required gradient.

3. However, this is subject to the overriding requirement that for instrument approaches, with a decision height below 200 ft. the minimum acceptable gross gradient for any aeroplane is 2.5% or the published aerodrome gradient whichever is the higher. *[JAR-OPS 1.510 (b)]*. If an aeroplane is unable to comply with this requirement then the decision height must be increased to a minimum of 200 ft. *[IEM-OPS 1.510 (b)]*.

WAT Limited Landing Weight Calculations. In the event of a missed approach the MRJT 1 must attain a minimum gross gradient of 2.1% with the critical engine inoperative and the remaining engine set at maximum take-off power and the undercarriage retracted. The graph provided in the Performance Manual for this purpose is titled 'Landing Performance Climb Limit' at CAP 698 page 92 and uses the datum conditions of air condition set to automatic, the anti-ice bleeds are off and that no icing conditions are experienced when the forecast landing temperature is below + 8°C.

4. The main graph has a flat rating cut-off at ISA +15°C and has a grid provided to account the flap position which has the reference–line at the 40° setting. The input values of ambient temperature and aerodrome pressure altitude account for the air density. Below the main graph are instructions and tables to enable correction to be made for any deviation from the datum conditions.

EXAMPLE 17-1

EXAMPLE

Given: Aerodrome pressure altitude 2000 ft; Ambient temperature +33°C; Flaps 30°; A/C Auto; Anti – ice off; No icing forecast. Calculate the WAT limited landing weight.

SOLUTION

Enter the carpet at 33°C. Travel vertically to intersect the Aerodrome Pressure Altitude 2000 ft. From this point move horizontally left to the flap reference–line. Now parallel the grid to 30° of flap. Continue horizontally left to read the WAT Limited Landing weight as 60,400 kgs.

EXAMPLE 17-2

EXAMPLE

Given: Aerodrome pressure altitude 6000 ft; Ambient temperature +5°C; Flaps 15°; A/C off; Icing is forecast; Engine and wing anti-ice on. Calculate the WAT limited landing weight.

SOLUTION

WAT landing weight = 62,200 + 1440 kgs (A/C off) – 4,960 kgs. (icing forecast) – 5,800 kgs. (Engine and wing anti-ice) = 52,880 kgs.

EXAMPLE 17-3

EXAMPLE

Given: Aerodrome pressure altitude 4,000 ft; Ambient temperature +10°C; Air conditioning off; Flaps 40°; Engine anti-ice bleed on. Icing conditions are forecast during flight. Calculate the WAT limited landing weight.

SOLUTION

WAT limited landing weight = 59,700 kgs. + 1,250 kgs. (A/C off) 550 kgs (Eng. A/I on) = 60, 400 kgs.

EXAMPLE 17-4

EXAMPLE

Given: Aerodrome Pressure Altitude 7000 ft; Flaps 15°; A/C off; Wing and engine anti-ice off; Calculate the maximum permitted temperature for landing at a weight of 56,500 kgs. The field-length is not limiting.

SOLUTION

Corrected landing weight = 56,500 – 1440 = 55,060 kgs. From main graph maximum temperature + 30°C.

EXAMPLE 17-5

EXAMPLE

Given: Aerodrome pressure altitude 5000 ft; Ambient temperature +30°C; No icing is forecast; A/C Auto; A/I off; Flaps 30°. Calculate the maximum permitted temperature for landing at a weight of 53,600 kgs. if the field-length is not limiting.

SOLUTION

+ 35°C.

The Field-Length Requirements

5. The landing distance requirements are specified in *JAR-OPS 1.515* for a dry runway and *JAR-OPS 1.520* for wet or contaminated runways.

Landing Distance Correction. If VAT has to be adjusted to allow for windshear, gusty or turbulent conditions and exceeds VREF + 7kts the LDR must be corrected by the following formula:

$$LDR \times \frac{VAT^2}{(VREF + 7kt)^2}$$

Dry Runway Requirements *(JAR-OPS 1.515 (a)*. The Landing Distance (LD) is from the threshold to the point at which the aeroplane comes to rest. The normal approach is 3° to arrive at screen height 50 ft at a speed of 1.3 VS. At any aerodrome the LD must not exceed 60% of the LDA for turbo – jet aeroplanes, or 70% of the LDA for turbo-prop aeroplanes. The landing distance required (LDR) is the factorized landing distance and is that which is used in the performance landing field-length graphs. See Figure 17-1. The turbo-prop requirements are depicted at Figure 17-2.

FIGURE 17-1
Turbo-Jet Landing Distance (Dry Runway)

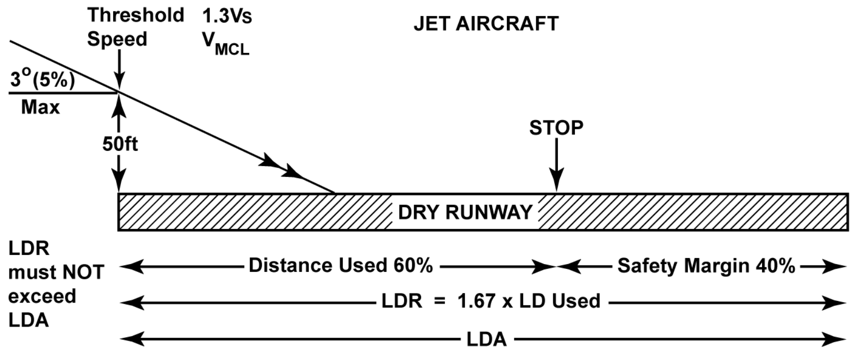
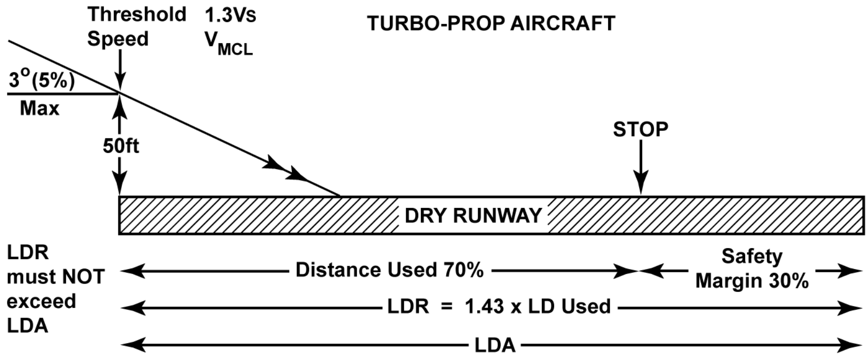


FIGURE 17-2
Turbo-Prop
Landing Distance
(Dry Runway)



Steep Approaches. At particular aerodromes the JAA may approve a steep approach procedure having a glideslope of 4.5° or more and a specified screen height between 50 ft and 35 ft. For such an approval the flight manual must contain any limitations on such an approach and a means of determining the landing distance required. Each aerodrome at which this procedure is to be employed must have at least a visual guidance system and specified weather minima for each runway.

Wet Runway Requirements *[JAR–OPS 1.520 (a), (c) and (e)]* If the meteorological actual report or forecast for the estimated time of arrival indicates that the runway will be wet, that is covered in water less than 3 mm deep then the LDR is to be 115% of the dry runway LDR, which is the dry runway LDR x 1.15.

6. However, if the landing distance available is less than this amount but greater than the dry runway LDR then it may be used provided that the Flight Manual includes specific additional information regarding the LDR on wet runways. The calculated LDR must still comply with the requirement of *JAR-OPS 1.515 (a) (1) and (2)* i.e. the LDR for a wet runway must not exceed 52% of the LDA for turbo- jet aeroplanes (see Figure 17-3) or 61% for turbo-prop aeroplanes (see Figure 17-4).

FIGURE 17-3
Turbo-Jet Landing Distance (Wet Runway)

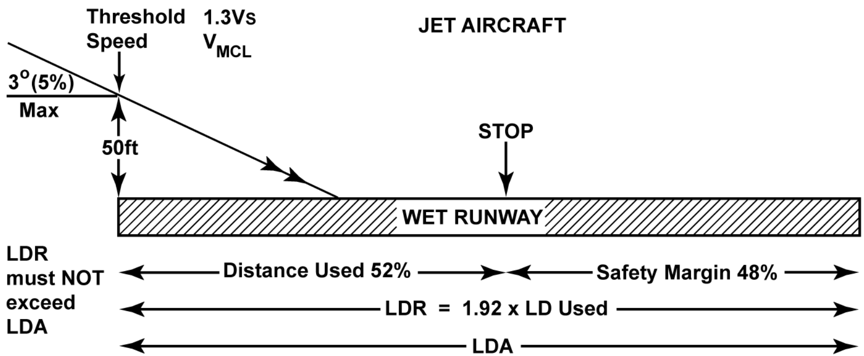
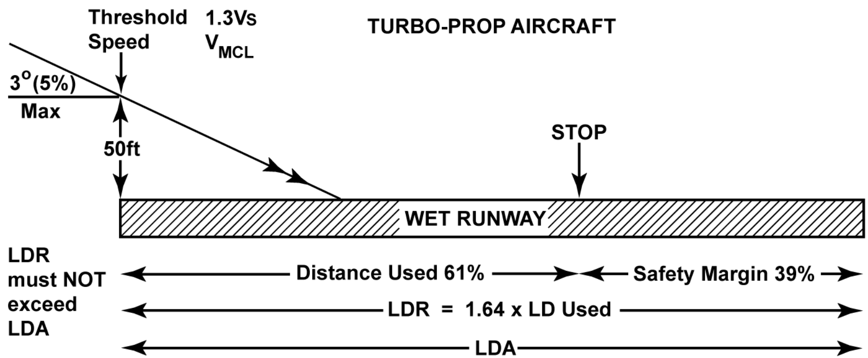


FIGURE 17-4
Turbo-Prop Landing Distance (Wet Runway)



Contaminated Runway Requirements *[JAR–OPS 1.520 (b), (d) and (e)]*. If the meteorological actual report or forecast conditions for the estimated time of arrival imply that the runway is likely to be contaminated, that is 25% of the surface covered with a significant depth of contaminant, then the LDR is to be 115% of the LDR determined from the contaminated landing distance data provided the wet runway LDR, whichever is the greater. However, if the landing distance available is less than this amount and the runway has been specially prepared but is of greater distance than the dry runway LDR, then it may be used, provided that the flight manual includes specific additional information regarding the LDR on contaminated runways. The requirement that the LD does not exceed 60% on the LDA for turbo – jet aeroplanes or 70% of the LDA for turbo – prop aeroplanes does not apply to the contaminated runway LDR.

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Landing Field-Length Calculations

7. There two distinct types of Field-Length Landing calculation that may be made, they are 'scheduled or planned' in accordance with *JAR-OPS 1.475 (a) (1)* and 'in-flight' to comply with *JAR-OPS 1.475 (a) (2)*. The scheduled or planned calculations are made before take-off from the departure aerodrome, which may be a considerable time before the estimated time of landing. In-flight calculations are made at the time of the revision of the operational plan and consequently will be a shorter time lapse to the estimated time of landing.

All landing calculations must account the following:

(a) Aerodrome pressure altitude and ambient temperature

(b) 50% of headwind or 150% of tailwind

(c) The runway slope in the direction of landing if it is greater than ± 2%, which is the normal maximum in Europe. *[JAR-OPS 1.515 (b) (1), (2) and (3)]*.

8. When 'scheduling' or 'planning' a landing, using forecast information, particular despatch rules apply which are designed for maximum safety without being unnecessarily restrictive on the operator. The rules are as follows:

(a) The aeroplane is assumed to land on the most favourable runway in still air conditions. This will normally be the longest runway, but a shorter runway with an uphill slope in excess of 2% may prove to be more beneficial. *[JAR-OPS 1.515 (c) (1)]*.

(b) The aeroplane is assumed to land on the runway most likely to be used, accounting the wind velocity, landing aids, obstacle clearance and aeroplane ground handling characteristics. At most modern airports all available runways for landing are able to cope with these criteria. It, therefore, is most likely that the runway assigned for landing will be determined by the wind direction. Thus the most favourable runway in the forecast wind should be assumed. *[JAR-OPS 1.515 (c) (2)]*.

(c) The lowest landing weight of a. and b. above is to be used as the field-length limited landing weight *[IEM-OPS 1.515 (c) (3)]*. If a destination has only one runway and the aeroplane is unable to land in still air conditions, but requires a specific headwind component to comply with the requirements, then it may still be despatched provided 2 alternate aerodromes are designated at which compliance with **all** of the requirements can be attained. In flight before commencing the approach the commander must be satisfied that the aeroplane can comply with the WAT limit and the missed approach gradient requirement.

(d) If an operator is unable to comply with the forecast wind requirement, but is able to comply with the still air requirement, then the aeroplane may be despatched if an alternate is designated at which **all** the landing requirements can be attained. This situation may occur at an aerodrome that has a single one- way runway on which a tailwind is forecast.

9. Although the calculation process for both are similar, the despatch rules must be obeyed when scheduling or planning a landing; they are not an in-flight consideration.

In-Flight Landing Weight Calculations

(a) Using all the details given, except runway slope unless it exceeds 2%, determine the Field-Length Limited Landing Weight.

(b) Determine the WAT Limited Landing Weight.

(c) Compare 1 and 2 with the C of A limit to determine the maximum landing weight.

10. The graphs provided for field length calculations is on CAP 698 page 91 and titled 'Landing Performance Field Length Limit'. It is already factorized by 1.67 for a dry runway. The additional 1.15 factor required for a wet runway is applied automatically by using the surface condition grid. The graph has the following datum conditions:

(a) Still Air Conditions.

(b) Runway Surface Dry.

(c) Flap Position 40°.

11. If the actual conditions differ from the data then corrections must be made. If the spoilers are set to manual with anti-skid operative then the landing distance available must be reduced by 198 m (650 ft.). The other conditions are corrected within the graph by a series of grids. The wind grid is already factorized in accordance with JAR-OPS by 50% headwind and 150% tailwind, thus the grid can be entered with the actual along track wind component.

12. The main graph is divided in two. The upper part of the main graph is for use when the anti-skid is operative, and the lower part of the graph is used when the anti-skid system is inoperative, with spoilers either automatic or manual.

In-Flight Calculations. The procedure for calculating the field-length limited landing weight is:

(a) Correct the LDA, if necessary, for spoilers set to manual.

(b) Enter the left vertical axis with the LDA.

(c) Proceed horizontally right to the wind component reference-line. Parallel the grid lines to the appropriate value of wind component.

(d) Continue horizontally right to the runway condition reference-line. If the runway is dry continue horizontally right. If the runway has up to 3 mm of water on the surface then from the reference –line parallel the grid lines to the wet condition.

(e) Recommence travelling horizontally right to the flap position reference-line. If they are set to 40° continue horizontally, if not parallel the grid lines to the input appropriate to the setting.

(f) From this point continue horizontally right to intersect the line appropriate to the aerodrome pressure altitude. From the intersection drop a vertical to the carpet to read the field –length limited landing weight.

EXAMPLE 17-6

EXAMPLE

Given: Aerodrome pressure altitude 2000 ft; LDA 2,530m;

Runway surface wet; Flaps 30° set. Overhead destination. Automatic spoilers; Anti-skid inoperative; Wind Component 20 kts. head. Calculate the field–length limited landing weight.

SOLUTION

Field-length limited landing weight = 46,900 kgs.

EXAMPLE 17-7

EXAMPLE

Given: Aerodrome pressure altitude 4000 ft; LDA 1555 m; Runway surface dry; Flaps 40° set. Overhead destination. Automatic spoilers; anti – skid operative; Wind component 20 kts. Head. Calculate the field-length limited landing weight.

SOLUTION

Field-length limited landing weight = 56,100 kgs.

EXAMPLE 17-8

EXAMPLE

Given: Aerodrome pressure altitude 6000 ft; LDA 2000 m; Runway surface dry; Flaps 40° set. Overhead destination. Spoilers manual; Anti-skid operative; Wind component 10 kt tail. Calculate the field-length limited landing weight.

SOLUTION

LDA = 2000 – 198 m = 1802 m. Field-length limited landing weight = 50,400 kgs

To calculate the landing distance required adopt the following procedure:

(a) Enter the right carpet at the landing weight, travel vertically to intersect the aerodrome pressure altitude in the grid appropriate to the configuration of the anti-skid unit.

(b) Now move horizontally left to the flap setting. From this position parallel the grid to the reference-line.

(c) Continue horizontally left to the condition of the runway surface. If it is wet parallel the grid – lines to the reference-line.

(d) Recommence travelling horizontally left to the appropriate wind component and parallel the grid lines to the reference-line.

(e) From this position continue horizontally to the left vertical axis to read the LDR.

(f) Correct the LDR if the spoilers are set to manual.

(g) If the landing distance used has to be found then divide the LDR by the appropriate factors.

EXAMPLE 17-9

EXAMPLE

Given: Aerodrome pressure altitude 3000 ft; Landing weight 55,000 kgs; Spoilers automatic; Anti-skid inoperative; Flaps 30°; Runway surface dry; wind component 20 kts. Head. Calculate the landing distance required and used.

SOLUTION

LDR = 8425 ft =2568.6 m. LD used = 2568.6 ÷ 1.67 = 1533m.

EXAMPLE 17-10

EXAMPLE

Given: Details as for Example 13-9 except anti-skid operative and spoilers are at manual. Calculate the landing distance required and used.

SOLUTION

LDR = 5,150 ft + 650 ft = 5,800ft = 1768.3m

LD used = 1768.3 ÷ 1.67 = 1059m

EXAMPLE 17-11

EXAMPLE

Given: Aerodrome pressure altitude 2000 ft; Landing weight 50,000 kgs; Spoilers manual; Anti-skid inoperative; Flaps 15°; Runway surface dry; Wind component 10 kts tail. Calculate the landing distance required and used.

SOLUTION

LDR = 10450 ft = 3186 m.

LD used = 3186 ÷ 1.67 = 1897m

EXAMPLE 17-12

EXAMPLE

Given: Aerodrome pressure altitude 6000 ft; Landing weight 52,000 kgs; spoilers automatic; anti-skid operative; flaps 40° Runway Surface wet; Wind component 15 kt tail; Calculate the landing distance required and used.

SOLUTION

LDR = 8000 ft = 2439m.

LD used = 2439 ÷ 1.67 ÷ 1.15 = 1270m.

Scheduled Landing Weight Calculations

13. The despatch rules quoted in paragraph 8 do not require runway slope to be accounted unless it exceeds 2%. No provision is made in CAP 698 for such an eventuality so it can be safely ignored. As a result the scheduled field-length limited landing weight is usually determined by the longest runway in still air. However, with certain combinations of runway lengths and wind component, the forecast wind condition can be limiting. To ease the problem of applying the scheduling rules for a multi-runway destination draw a table such as the one at Figure 17-5.

If the aerodrome has only one runway, such a table is unnecessary. The field-length limited landing weight is determined by the still-air condition if it is open both ways or one-way with a forecast headwind. For a one-way runway with a forecast tailwind then the forecast wind condition will be limiting.

It is essential to check that the crosswind on a runway does not exceed the maximum permitted, which for CAP 698 is 33 knots for a dry or wet runway but reduces to 10 knots for an icy, very slippery or contaminated runway. If the calculated crosswind exceeds the limit, although the forecast wind landing weight cannot be calculated, the still air value must still be calculated for comparision purposes.

Similarly, if a runway is too short in still air conditions but the forecast headwind makes it acceptable then the forecast wind landing weight must still be calculated for comparision purposes.

FIGURE 17-5

	Still Air	Forecast Wind
Runway A: Flaps ° LDA = m = ft Surface Dry/Wet	 kgs	WC kts. H/T X-Wind kts kgs
Runway B: Flaps ° LDA = m = ft Surface Dry/Wet	 kgs	WC kts. H/T X-Wind kts kgs
Highest	kgs	kgs
Lowest (FLL LDG WT)		kgs
WAT Limit	kgs	
C of A Limit	54,900 kgs.	
Scheduled Landing Weight		

Procedure

(a) Complete the details for each runway. LDA factored, if necessary, because of surface condition or aircraft configuration. Enter slope only if it exceeds 2%.
Wind component, if open both ways use runway with the head component, if runway is only open one way use actual along track component. Insert wind component in forecast wind column.

(b) Calculate the landing weight for each runway both for still air and the forecast wind.

(c) Select the highest still air landing weight. This is the most favourable in still air.

(d) Select the highest forecast wind landing weight. This is the most favourable in the forecast wind.

(e) Select the lowest of the two highest weights. This is the field-length limited landing weight.

(f) Calculate the WAT limited landing weight.

(g) Enter the maximum certificated landing weight as the certificate of airworthiness (C of A) limit.

(h) Compare (e), (f) and (g). Select the lowest as the maximum scheduled landing weight.

EXAMPLE 17-13

EXAMPLE

Given: Aerodrome pressure altitude 2000 ft; Ambient temperature + 30°C; W/V 270/30; Flaps 40°; Anti-skid operative; Spoilers automatic; ACS on. Anti-ice off; No icing forecast below + 8°C.

(a) Runway 30; open both ways; LDA 1500 m.
Runway slope 1 % up/down; surface wet.

(b) Runway 22; open one way; LDA 1600 m.
Runway slope 2 % up; surface wet.

Calculate the maximum scheduled landing weight.

SOLUTION

	Still Air	Forecast Wind
Runway 30: Flaps 40° LDA = 1500m = 4920ft. Surface wet	45,200 kgs.	WC26kts.H X-Wind 15 kts 52,600 kgs.
Runway 22: Flaps 40° LDA = 1600m = 5248ft Surface wet	50,000 kgs.	WC 19 kts. H X-Wind 23 kts 54,300 kgs.
Highest	50,000 kgs.	54,300 kgs.
Lowest (FLL LDG WT)	50,000 kgs	
WAT Limit for Amb + 30°C	60,000 kgs	
C of A Limit	54,900 kgs.	
Scheduled Landing Weight	50,000 kgs	

EXAMPLE

Given: Aerodrome pressure altitude 4000 ft; Ambient temperature + 20°C; W/V 340/10; Flaps 40°; Anti-skid inoperative; Spoilers manual; ACS on. Anti-Ice off; No icing forecast below + 8°C.

(a) Runway 10; Open one way; LDA 3000 m
Runway slope 2% up surface dry

(b) Runway 20; Open Both ways; LDA 2800 m
Runway Slope 1 % down; surface dry'

Calculate the maximum scheduled landing weight.

SOLUTION

	Still Air	Forecast Wind
Runway 10: Flaps 40° LDA = 3000m = 9840 ft Surface Dry	60,700 kgs.	WC 5 kts. T 57000 Kgs.
Runway 20/02: Flaps 40° LDA 2800m = 9184 ft Surface Dry	55,600 kgs.	WC 7.5 kts. H 58000 Kgs.
Highest	60,700 kgs.	58,000 kgs.
Lowest (FLL LDG WT)	58,000 kgs.	
WAT Limit Amb + 20°C	59,400	
C of A LIMIT	54,900 kgs.	
Scheduled Landing Weight'	54,900 kgs	

EXAMPLE

Given: Aerodrome pressure altitude 6000 ft; Ambient temperature + 30°C; W/V 000/40; Flaps 15°; Anti-skid operative; Spoilers manual; ACS on; Anti-ice off; No icing forecast below + 8°C.

Calculate the maximum scheduled landing weight.

(a) Runway 18/36; Open both ways; LDA 2200 m Runway slope 0% Up/Down; Surface dry.

(b) Runway 09; Open one way; LDA 2330 m. Runway slope 2 % Down; Surface dry.

SOLUTION

	Still Air	Forecast Wind
Runway 36 Flaps 15° LDA 2200 m = 7216 ft - 650 ft = 6566 ft Surface Dry	51,300kgs.	WC 40 kts. H X-wind 0 kts 65,700 kgs.
Runway 09 Flaps 15° LDA 2330 m = 7642 ft -650 ft = 6992 ft Surface Dry	53,400 kgs.	WC 0 kts. X-wind 40 kts Outside of X-wind limits
Highest	53,400 kgs.	65,700 kgs.
Lowest (FLL LDG WT)	53,400 kgs.	
WAT Limit Amb + 30°C	57,000 kgs.	
C of A Limit	54,900 kgs.	
Scheduled Landing Weight	53,400 kgs	

EXAMPLE

Given: Aerodrome pressure altitude 2000 ft; Ambient temperature -10°C; W/V 210/15; Flaps 40°; Anti-skid operative spoilers manual; ACS on; Eng and wing anti-ice on; Icing is forecast below + 8°C.

(a) Runway 27/09; Open both ways; LDA 2100 m Runway slope 0%; Surface dry.

(b) Runway 17; Open one way; LDA 2060 m. Runway Slope 2% up; Surface dry.

Calculate the maximum scheduled landing weight.

SOLUTION

	Still Air	Forecast Wind
Runway 27 Flaps 40° LDA 2100 m = 6888 ft -650 ft = 6238 ft Surface dry	63,300 kgs	WC 7.5 kts. H 13 kts. X–Wind 64900 kgs
Runway 17 Flaps 40° LDA 2060m = 6757 ft -650 ft = 6107 ft Surface dry	62,600 kgs.	WC 11.5 kts. H 9.6 kts. X-Wind 64700 kgs.
Highest	63,300 kgs.	64,900 kgs.
Lowest (FLL LDG WT)	63,300 kgs	
WAT Limit Amb –10°C	62,200 – 4830 – 5250 = 52,120 kgs.	
C of A Limit	54,900 kgs.	
Scheduled Landing Weight	52,120 kgs	

EXAMPLE 17-17

EXAMPLE

Given: Aerodrome pressure altitude 3000 ft; Ambient temperature -5°C; W/V 270/20; Flaps 30°; Anti-skid inoperative spoilers automatic; ACS OFF; Engine and wing anti-ice on; Icing is forecast below + 8°C.

Runway 21/03; Open both ways; LDA 2600 m. Runway slope 2 % up/down; Surface dry.

Runway 30/12; Open both ways; LDA 2400 m Runway slope 1 % up/down; surface dry.

Calculate the Maximum schedule landing weight.

SOLUTION

	Still Air	Forecast Wind
Runway 21 Flaps 30° LDA 2600m = 8528 ft Surface dry	49,200 kgs	WC 10 KTS H 17 ½ KTS. X-Wind 52,100 kgs
Runway 30 Flaps 30° LDA 2400m = 7872 ft Surface dry	43,000 kgs	WC 17 ½ kts H 10 kts. X-Wind 49,900 kgs
Highest	49,200 kgs.	52100 kgs.
Lowest (FLL LDG WT)	49,200 kgs.	
WAT Limit Amb 0°C	63000 + 1310 – 4730 kgs. -5350 kgs = 54230 kgs	
C of A Limit	54,900 kgs.	
Scheduled Landing Weight	49200 kgs	

EXAMPLE

Given: Aerodrome pressure altitude 2000 ft; ACS on; Ambient temperature +40°C; W/V 340/9; Flaps 15°; Anti-skid operative; Spoilers manual; Engine and wing anti-ice off; Icing is not forecast below +8°C

Runway 10; Open one way; LDA 2500m; Surface condtion wet

Runway 02; Open both ways; LDA 2300m; Surface condition wet

Calculate the maximum scheduled landing weight.

SOLUTION

	Still Air	Forecast Wind
Runway 10; Flaps 15° LDA 2500m = 8200 ft -650 ft = 7550 ft Surface wet	55,300 kgs	WC 4.5 kts tail X-Wind 7.8 kts 53,000 kgs
Runway 02; Flaps 15° LDA 2300m = 7544 ft - 650 ft = 6894 ft Surface wet	50, 600 kgs	WC 7 kts head X-Wind 5.8 kts 54,000 kgs
Highest	55,300 kgs.	54,000 kgs.
Lowest (FLL LDG WT)	54,000 kgs.	
WAT Limit	61,000 kgs	
C of A Limit	54,900 kgs.	
Scheduled Landing Weight	54,000 kgs	

Reduced Thrust Take-off - Class ‘A’ Aeroplanes

Calculation Procedure

Reduced Thrust Take-off - Class 'A' Aeroplanes

1. Whenever the TOW is less than the field-length limited TOW there is clearway which is unused. This may be utilized to increase TOW if it was restricted by the WAT limit, the tyre speed limit or the obstacle clearance requirement. If an increase of TOW is not needed then the unused clearway may be used for a reduced thrust take-off. Not only will this technique reduce engine wear, thus prolonging engine life; it will also reduce engine noise. This procedure is known by a variety of different names such as 'Variable Thrust Take-off,' 'Graduated Power Take-off' or 'Factored take-off Thrust'. Use of the reduced thrust take-off technique is prohibited if the runway is contaminated, icy or very slippery. Also it is not permitted to be used if the anti-skid is inoperative or the power maintenance computer (PMC) is off.

2. For all aeroplanes using this technique there is a limit to the maximum thrust reduction permissible. Some aircraft are restricted to a maximum reduction to the Engine Pressure Ratio (EPR) others are limited by a percentage reduction to the maximum take-off thrust. Such is the case with the MRJT, which is confined to a maximum reduction of 25% of the take-off power. To employ this technique it is essential to determine the most limiting operational parameter to enable the precise reduction of thrust to be calculated. The only factor common to all operational parameters is that of ambient temperature. A series of false or assumed temperatures is determined by using the actual TOW and ambient conditions in each graph.

3. There are four operationally limiting parameters for which an assumed temperature must be calculated. They are the field-limit, the tyre speed limit, the climb limit and the obstacle limit. The lowest of these assumed temperatures is then the most limiting, but it must not exceed the maximum or be below the minimum permissible as stated in the tables.

Calculation Procedure

(a) Determine the assumed temperature for each limiting parameter:

(i) Enter the Take-Off Performance 'Field Limit' graph, CAP 698 page 55, with the field length available, runway slope, wind component, flap position, TOW (corrected for air conditioning and engine anti-ice if necessary) and aerodrome pressure altitude. Extract the 'Assumed Temperature'.

(ii) Enter the Tyre Speed Limit graph, CAP 698 page 59. Correct the TOW for flaps and/or speed rating and wind component to become an equivalent TOW for 5° Flaps, 225 mph tyres in still air. Enter the left vertical axis at this revised TOW travel horizontally right to intercept the Aerodrome Pressure Altitude. At this point read the 'Assumed Temperature'.

(iii) Enter the Climb Limit graph, CAP 698 page 57. Correct the TOW for Air Conditioning packs off and Engine Anti-Ice, if necessary, to obtain an equivalent TOW with air conditioning on and the engine anti-ice off. Enter the left axis at this revised TOW, if flaps are 5° proceed horizontally right through the first grid, if flaps are 15° then parallel the grid to the Flaps Reference Line then proceed horizontally right. Continue horizontally right to intersect the Aerodrome Pressure Altitude. Read the 'Assumed Temperature' at this point.

(iv) Enter the Obstacle Limits graph, CAP 698 pages 82 or 83. Enter the lower left vertical axis at the Obstacle Height corrected for runway slope. Travel horizontally right to intersect the Obstacle Distance from the brakes release point. Move vertically to the temperature grid reference line. Mark this point. Now enter the ceiling of the graph at the TOW drop vertically to the Wind Component then parallel the grid lines to the wind component Reference-Line. From this point drop vertically to the Aerodrome Pressure Altitude then parallel the grid lines to the Reference-Line. Drop a vertical from this point through the temperature grid. From the mark previously made on the temperature grid Reference-Line parallel the grid-lines to intersect the vertical line just drawn. From this point travel horizontally left to read the assumed temperature.

(b) Select the lowest assumed temperature form (i), (ii), (iii), and (iv).

(c) Enter the page titled 'Assumed Temperature Reduced Thrust From Derate' CAP 698 pages 78.

(i) Enter top table 'Maximum Assumed Temperature' at the left column with the ambient temperature. Travel horizontally right to the Aerodrome Pressure Altitude to read the maximum 'Assumed Temperature'.

(ii) Enter CAP 698 Page 79 Top Table. Bottom line read 'Minimum Assumed Temperature' in the appropriate Aerodrome Pressure Altitude column.

(iii) Check the 'Assumed Temperature' from (b) above is not outside of these limits, if it is use the limiting 'Assumed Temperature'.

(d) Enter the Top Table at the selected 'Assumed Temperature' in the left column and travel horizontally right to the Aerodrome Pressure Altitude to read the maximum take-off % N1. Add 1.0% N1 if the Air Conditioning is off.

(e) Enter the Lower Table. Subtract the ambient temperature from the 'Assumed Temperature' and enter the left column of the table at this value. Travel horizontally right to the appropriate ambient temperature column to read the % N1 adjustment.

(f) Subtract the value determined at (e) above from the value found at (d). This is the reduced thrust take-off % N1 to be used.

(g) The recommended power setting to be made in the event of an engine failure during a reduced thrust take-off is derived from the normal maximum take-off % N1 table at ambient temperature. Figure 4.11

(h) For the reduced thrust take-off speeds enter the 'Take-Off Speed' page at the assumed temperature for V1, VR and V2 but for VMCG at the ambient temperature.

(i) To the V1 calculated apply corrections for runways slope, wind component, clearway and stopway as appropriate. The resulting V1 may not be less than VMCG, if it is then make V1 equal to VMCG.

Reduced Thrust Take-off - Class 'A' Aeroplanes

EXAMPLE

Given: BRP Elevation 2,000 ft amsl; R/W Slope 2% Down; TOW 50,000 kgs; Ambient temperature 0°C TODR 4,500 ft; TODA 6,500 ft; Wind component 10 kts Head; Flap 15°; PMC on; A/C on; Engine A/I on; Tyre Speed Rating 210 mph; Obstacle elevation 2300 ft amsl; Obstacle distance from BRP 24,000 ft;
Calculate the reduced thrust take-off power setting, VMCG, V1, VR and V2.

SOLUTION

1a. Field Limit Graph. Figure 4.4
A/C Correction 0 kgs; Engine A/I Correction + 350 kgs
Equivalent TOW 50,350 kgs; **Assumed Temperature + 52°C.**

1b. Tyre Speed Limit Graph. Figure 4.6
Flap Correction 0 kgs; Tyre speed correction + 1500 kgs;
WC correction – 4000 kgs; Equivalent TOW 47,500 kgs; **Assumed Temperature N/L °C.**

1c. Climb Limit Graph. Figure 4.5
A/C Correction 0 kgs; Engine A/I Correction +190 kgs;
Equivalent TOW 50190 kgs; **Assumed Temperature + 41½°C.**

1d. Obstacle Limits Graph. Figure 4.21
R/W Slope Correction – 90 ft; RZ elevation 1910 ft AMSL;
Obstacle Height 390 ft above RZ; **Assumed Temperature + 36°C.**

2. Lowest assumed temperature = +36°C.

3. Assumed Temperature Reduced Thrust from Derate Page. Figure 4.17

(i) Maximum Assumed Temperature Permitted +58°C.

(ii) Minimum Assumed Temperature Permitted +26°C.

(iii) Assumed Temperature to be used +36°C.

4. Maximum take-off % N1 = 95.5%.

5. % N1 adjustment = 5.6%.

6. Reduced thrust take-off % N1 95.5 – 5.6 = 89.9 %.

7. Recommended go-around Figure 4.11 % N1 = 92.1 % at ambient temp.

8. Take-off speed page. Figure 4.9 Column C At assumed temperature V1 = 124 kts; VR = 125 kts; V2 = 134 kts; V1 adjustment = - 2 kts.

9. Corrected V1 = 122 kts. At ambient temp VMCG = 113 kts.

EXAMPLE 18-2

EXAMPLE

Given: TOW 52,400 kgs; Ambient temperature – 5°C; BRP elevation 1000 ft. amsl; R/W slope 2% up; TODR 5,800 ft; TODA 7,000 ft; Wind component 10 kts. Head; Flap 5°; PMC on; A/C on; Engine A/I on; Tyre speed rating 210 mph; Obstacle elevation 1,766 ft. amsl. Obstacle distance from BRP 28,000 ft;

Calculate the reduced thrust take-off power setting, VMCG, V1, VR and V2.

1a. Field Limit Graph. A/C correction 0 kgs; Engine A/I correction + 350 kgs. Equivalent TOW 52,750 kgs; **Assumed Temperature + 38°C.**

1b. Tyre Speed Limit Graph. Flap correction 0 kgs; Tyre speed correction + 9,600 kgs; WC correction – 4,000 kgs; Equivalent TOW 58,000 kgs; **Assumed Temperature N/L °C.**

1c. Climb limit graph. A/C correction 0 kgs; Engine A/I correction + 190 kgs. Equivalent TOW 52,590 kgs; **Assumed Temperature + 50°C.**

1d. Obstacle limits graph. R/W Slope correction + 116 ft; RZ Elevation 1116 ft. amsl; obstacle height 650 ft. above RZ; **Assumed Temperature + 35°C.**

2. Lowest Assumed Temperature = + 35°C.

3. (i) Assumed temperature reduced thrust from Derate page. Maximum assumed temperature permitted + 59°C.

(ii) Minimum assumed temperature permitted + 28°C.

(iii) Assumed temperature to be used + 35°C.

4. Maximum take-off % N_1 = 95.6%.

5. % N_1 adjustment = 6.2%.

6. Reduced thrust take-off % N_1 = 95.6% - 6.2% = 89.4%.

7. Recommended go-around % N_1 = 90.9% at Ambient temperature.

8. Take-off speed page. At assumed temperature V1 = 134kgs; VR = 136 kts; V2 = 145 kts; V1 Adjustment = + 1 kt.

9. Corrected V1 = 135 kts. at ambient temperature VMCG = 115 kts.

EXAMPLE 18-3

EXAMPLE

Given: TOW 54,150 kgs; Ambient Temperature + 5°C; BRP Elevation 2,000 ft. amsl; R/W Slope 2% down; TODR 5,200 ft; TODA 7500 ft; Wind Component 10 kts. Head; Flap 5°; PMC on; A/C on; Engine A/I on; Tyre speed rating 210 mph; Obstacle elevation 2,300 ft amsl. Obstacle distance from BRP 22,000 ft; Calculate the reduced thrust take-off power setting, VMCG, V1, VR and V2.

SOLUTION

1a. Field limit graph. A/C correction 0 kgs; Engine A/I correction + 350 kgs. Equivalent TOW 54,500 kgs; **Assumed Temperature + 46°C.**

1b. Tyre speed limit graph. Flap correction 0 kgs; Tyre speed correction + 9600 kgs; W/C correction - 4000 kgs; Equivalent TOW 59,750 kgs; **Assumed Temperature N/L °C.**

1c. Climb limit graph. A/C correction 0 kgs; Engine A/I correction + 190 kgs; Equivalent TOW 54,340 kgs; **Assumed Temperature + 41°C.**

1d. Obstacle limits graph. R/W Slope correction – 104 ft; RZ Elevation 1896 ft. amsl; Obstacle height 404 ft. above RZ; **Assumed Temperature + 19°C.**

2. Lowest assumed temperature = + 19°C.

3. Assumed temperature reduced thrust from derate page.

   (i) Maximum assumed temperature permitted + 58°C.

   (ii) Minimum assumed temperature permitted + 26°C.

   (iii) Assumed temperature to be used + 26°C.

4. Maximum take-off % N_1 = 96.5 %.

5. % N_1 adjustment = 3.4%.

6. Reduced thrust take-off % N_1 = 96.5 – 3.4% = 93.1%.

7. Recommended go-around % N_1 = 92.9% at ambient temperature

8. Take-off speed page. Column B At assumed temperature V1 = 137 kts; VR = 139 kts; V2 = 148 kts; V1 Adjustment = - 2 kts.

9. Corrected V1 = 135 kts. at ambient temperature VMCG = 113 kts.

Increased V2 Procedure - Class 'A' Aeroplanes

Improved TOW Calculations

Increased V2 Procedure - Class 'A' Aeroplanes

1. If the Take-off Distance required is considerably shorter than the Take-off Distance Available then the unused clearway may be used to improve the Limiting TOW. To do this it is necessary to hold the aircraft on the ground to attain a higher V_1 and V_R so that an increased V_2 is obtained in the climb. Normally after V_{LOF} the aeroplane should naturally accelerate to attain V_2, the free air safety speed, at screen height if one engine is inoperative or V_3 if all engines are operating. It is always assumed for obstacle clearance calculations that one engine has failed at V_1 and V_2 is the lowest safe speed at which to climb. The most efficient speed at which to climb is V_X for the best gradient of climb or V_Y to achieve the best rate of climb.

2. By holding the aeroplane on the ground to these higher speeds it can still climb and attain the minimum acceptable gradients in the take-off net flight path at a heavier TOW. If the object is simply to increase the TOW and obstacles encountered in the domain are not a problem then the factors that must be accounted are the field lengths available, the tyre speed limit and the WAT limit. These are all considerations which are in two graphs. Each graph produces an increase to the TOW of which the lower is used together with the associated speed increases. The increased V_1 may not exceed V_{MBE} and should be checked.

3. The two graphs to be used are titled 'Improved Climb Performance Field Length Limit' CAP 698 page 75, and 'Improve Climb Performance Tyre Speed Limit' CAP 698 page 76. Both graphs are divided such that the top set are for use with 5° take-off flap and the second set are for use with 15° take-off Flap. Each graph has speed increment sub-graph for determining the speed increment to apply to VR and V2.

Improved TOW Calculations

4. Having calculated the Field Length Limited TOW (Field length limit weight), the WAT Limited TOW (Climb limit weight) and the Tyre speed limited TOW (Tyre speed limits) turn to the Improved Climb Performance Field Length Limit graph and select the graph appropriate to the flap setting CAP 698 Page 75 Figure 4.15:

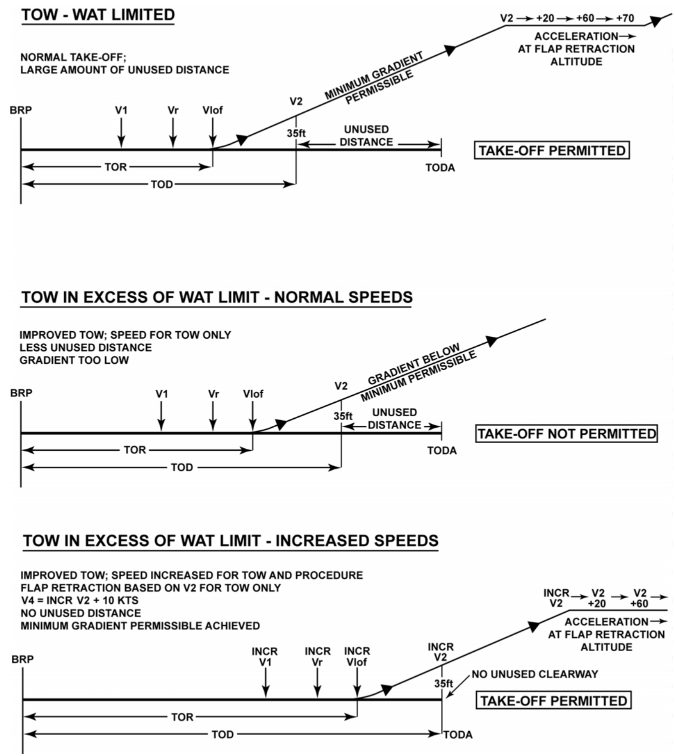
(a) Calculate the difference in weight between the field limit weight and the climb limit weight.

(b) Enter the carpet of the left graph with this difference and travel vertically to reach the Climb Limited TOW value interpolating between the solid graph lines. If the solid line to the left of the graph is intercepted this is the maximum limit to the Climb Weight Improvement.

(c) From this intersection travel horizontally left to the vertical axis to read the climb weight improvement and horizontally right to the vertical axis between the graphs to read the V2 increment.

Increased V2 Procedure - Class 'A' Aeroplanes

FIGURE 19-1
Increase V2 to improve TOW



(d) Now continue horizontally right to the Reference-Line of the right graph. From this position parallel the grid lines to intercept the vertical input of the normal Climb Limited TOW (WAT TOW). At this intersection continue horizontally right to the vertical axis to read the increment to be added to the VR and V2 calculated for the normal Climb Limited TOW.

(e) Calculate the difference in weight between the Tyre Speed Limit and the Climb Limited TOW. CAP 698 Page 75 Figure 4.16.

(f) Proceed using the improved Climb Performance Tyre Speed Limit graph as in (b). to (e). above.

(g) Select the Lower Climb Weight Improvement from the two graphs together with the associated speed increments.

(h) To the original Climb Limited TOW apply the weight improvement determined in (g).

(i) Calculate the V speeds for the Improved TOW calculated at (h).

(j) To the V speeds calculated at (i) add the speed increments at (g).

(k) Calculate VMBE and ensure V1 from (j) does not exceed it. If it does V1 must be reduced to equal VMBE and the TOW reduced accordingly.

5. The weights used in the following examples are to demonstrate the use of the graphs when employing the increased V2 technique to improve TOW. These would have been derived from a full take-off weight analysis.

EXAMPLE

Given: Flaps 5°; FLL TOW 60,000 kgs; Climb limit TOW 45,000 kgs; Tyre limit TOW 65,000 kgs. Aerodrome pressure altitude 2000 ft.; Ambient temperature +30°C R/W slope 2% up; WC 20 kts Head;

SOLUTION

FLL TOW – Climb limit weight = 60,000 – 45,000 = 15,000 kgs.

Enter left carpet of graph at 15,000 kgs. Move vertically to 45000 kgs. Climb weight improvement = 3900 kgs. V1 increment = 14 kts.

Continue horizontally to reference line then parallel grid lines to 45,000 kgs.

Continue horizontally right to read VR and V2 increment = 22 kts.

Tyre speed TOW – Climb limit weight = 65,000 – 45,000 = 20,000 kgs.

Climb weight improvement = 3900 kgs V1 increment = 14 kts. VR and V2 increment = 21 kts.

Climb weight improvement and V speed increments to be used 3900 kgs. V1 increment = 14 kts. VR and V2 increments = 21 kts.

Increased TOW = 45,000 + 3900 = 48,900 kgs.

V1 = 131 kts. VR = 132 kts. V2 = 140 kts.

Increased V1 = 145 kts. Increased VR = 153 kts. Increased V2 = 161 kts.

VMBE = 192 kts + 4 kts (runway slope) + 6 kts (wind component) = 202 kts.

EXAMPLE 19-2

EXAMPLE

Given: Flaps 15°; FLL TOW 55,000 kgs; Climb limit TOW 45,000 kgs; Tyre limit TOW 60,000 kgs. Aerodrome pressure altitude 1000 ft; Ambient temperature + 10°C. R/W slope 2% down WC 10 kts. Head.

SOLUTION

FLL TOW – Climb limit weight = 55,000 – 45,000 = 10,000 kgs.

Enter left carpet of graph at 10000 kgs. Move vertically to 45,000 kgs.

Climb weight improvement = 3100 kgs. V1 increment = 14 kts.

Continue horizontally to reference line then parallel grid lines to 45,000 kgs. Continue horizontally right to read VR and V2 increment = 24 kts.

Tyre Speed TOW – Climb limit weight = 60,000 – 45,000 = 15,000 kgs.

Climb weight improvement = 2700 kgs. V1 increment = 13 kts. VR and V2 increment = 18 kts.

Climb weight improvement and V speed increments to be used 2700 kgs. V1 increment = 13 kts. VR and V2 increments = 18 kts.

Increased TOW = 45,000 + 2700 = 47,700 kgs.

V1 = 118 - 2 = 116 kts. VR = 120 kts. V2 = 131 kts.

Increased V1 = 129 kts. Increased VR = 138 kts. Increased V2 = 149 kts.

VMBE not limiting. VCMG = 114 kts

Increased V2 Procedure - Class 'A' Aeroplanes

EXAMPLE

Given: Flaps 5°; FLL TOW 45,000 kgs; Climb limit TOW 40,000 kgs; Tyre limit TOW 50,000 kgs. Aerodrome pressure altitude 1000 ft.; Ambient temperature + 30°C. R/W Slope 0%; Wind component 0 kts.

SOLUTION

FLL TOW – Climb limit weight = 45,000 – 40,000 = 5000 kgs.

Enter left carpet of graph at 5000 kgs. Move vertically to 40,000 kgs. Climb weight improvement = 2050 kgs.

V2 increment = 6 kts.

Continue horizontally to reference line then parallel grid lines to 40,000 kgs. Continue horizontally right to read VR and V2 increment = 9 kts.

Tyre speed TOW – Climb limit weight = 50,000 – 40,000 = 10,000 kgs.

Climb weight improvement = 2450 kgs. V1 increment = 6 kts. VR and V2 increment = 9 kts.

Climb weight improvement and V speed increments to be used 2050 kgs. V1 increment = 8 kts. VR and V2 increment = 11 kts.

Increased TOW = 40000 + 2050 = 42050 kgs.

V1 = 117 kts. VR = 119.5 kts. V2 = 131 kts.

Increased V1 = 123 kts. Increased VR = 128.5 kts. Increased V2 = 140 kts.

VMBE not limiting. VMCG 113.5 kts