BASIC PERFORMANCE

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November 2012

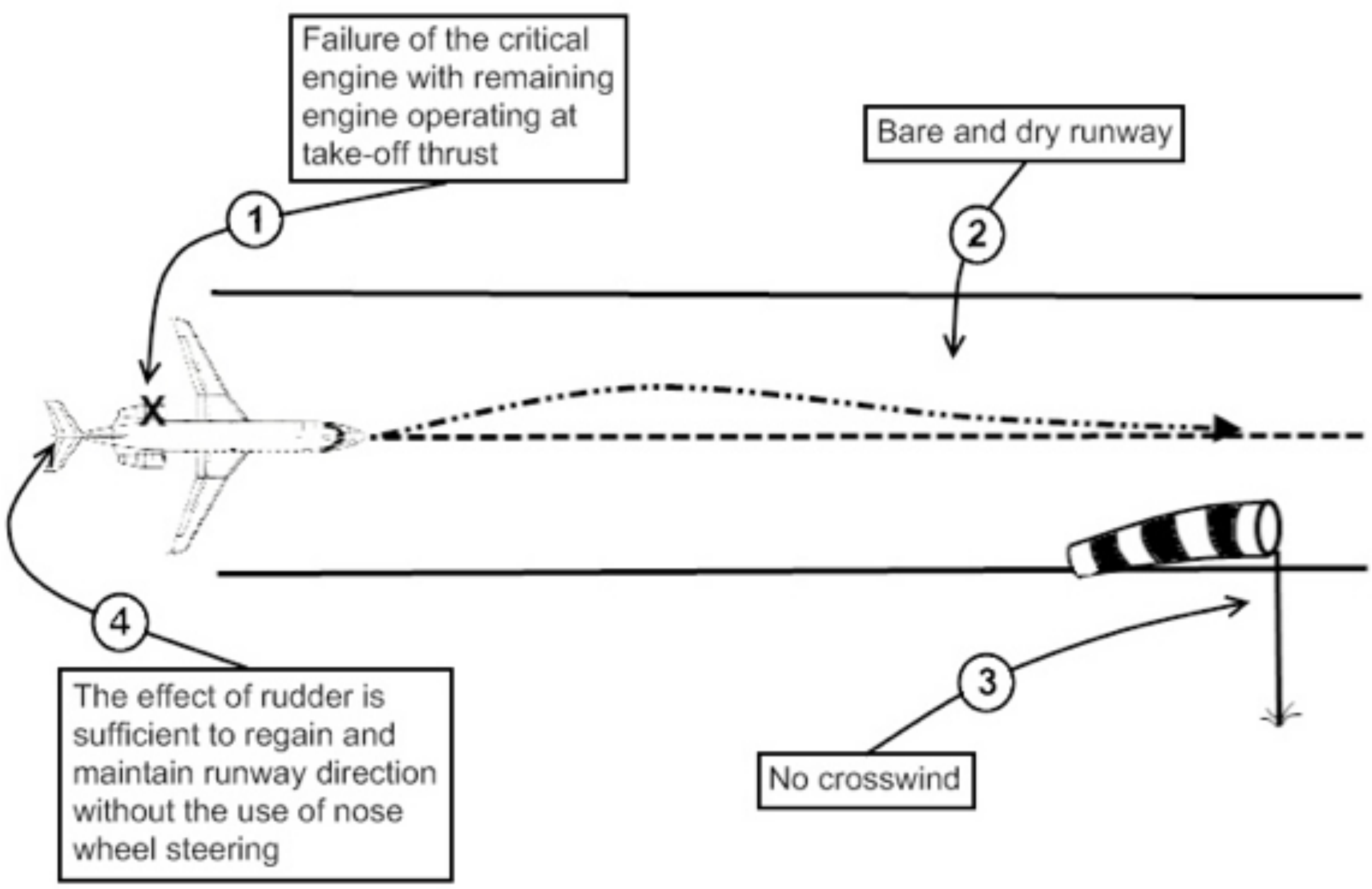
1.1 Minimum control speeds.

1.1.1 Minimum control speed on ground.

To determine the minimum speed at which the take-off can be continued after an engine failure, the Minimum control speed on ground (VMCG) is established during the certification test.

The certification criteria for this are :

- A sudden failure of the most critical engine, and take-off thrust on the operating engine.
- Bare and dry runway.
- No crosswind.
- Disconnected nosewheel steering in order to simulate a slippery runway.

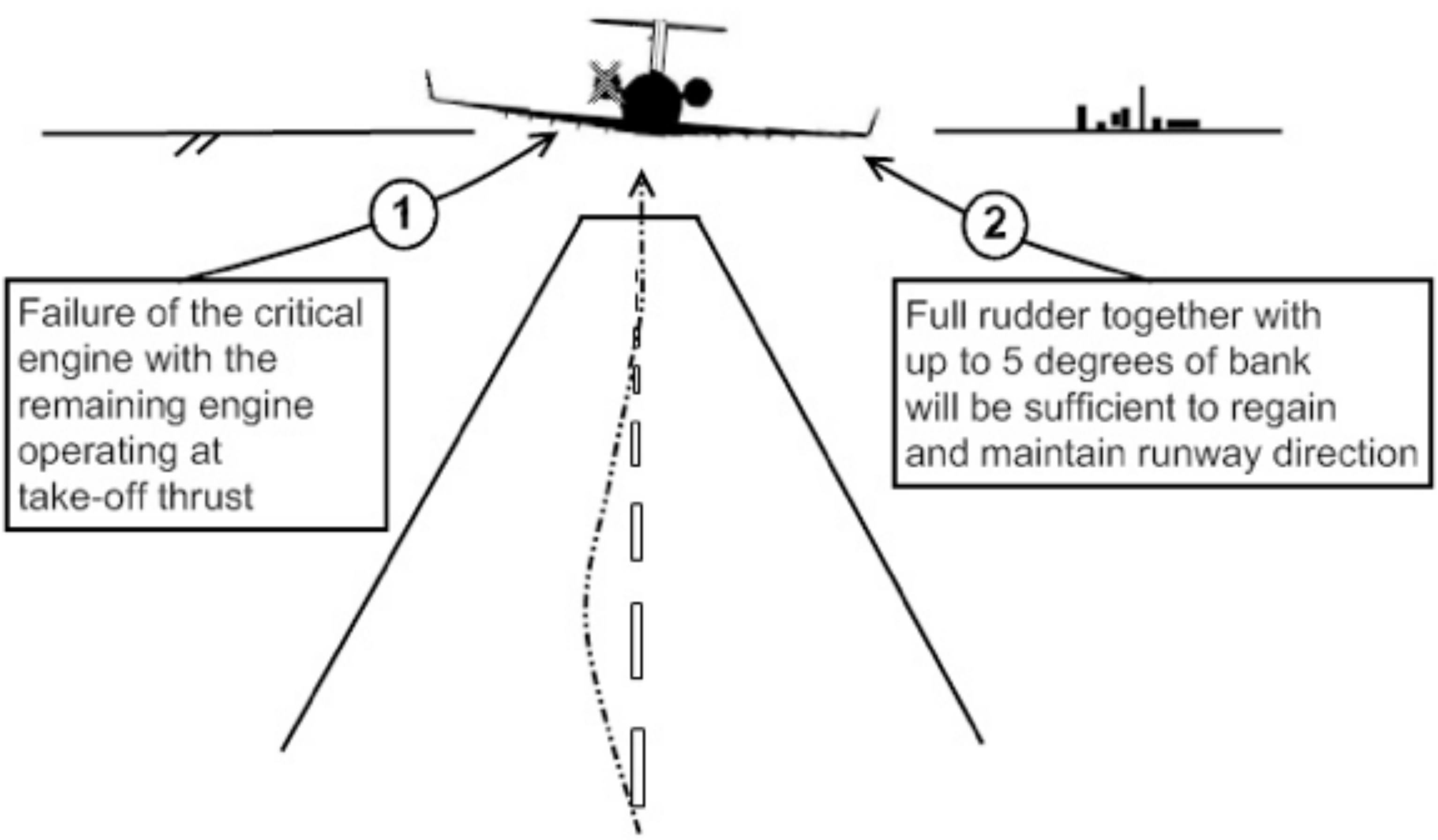


Using these criteria, VMCG is established as being the lowest speed at which rudder effect alone is sufficient to regain and maintain directional control after a sudden engine failure.

The major factor that affects VMCG is the difference in engine thrust. VMCG will therefore be lower at higher airport elevations and at higher OAT, due to the associated lower thrust.
In certain cases, a lower VMCG can be obtained by taking nosewheel steering into account. This lower VMCG, however, would be applicable only for a bare and dry runway.

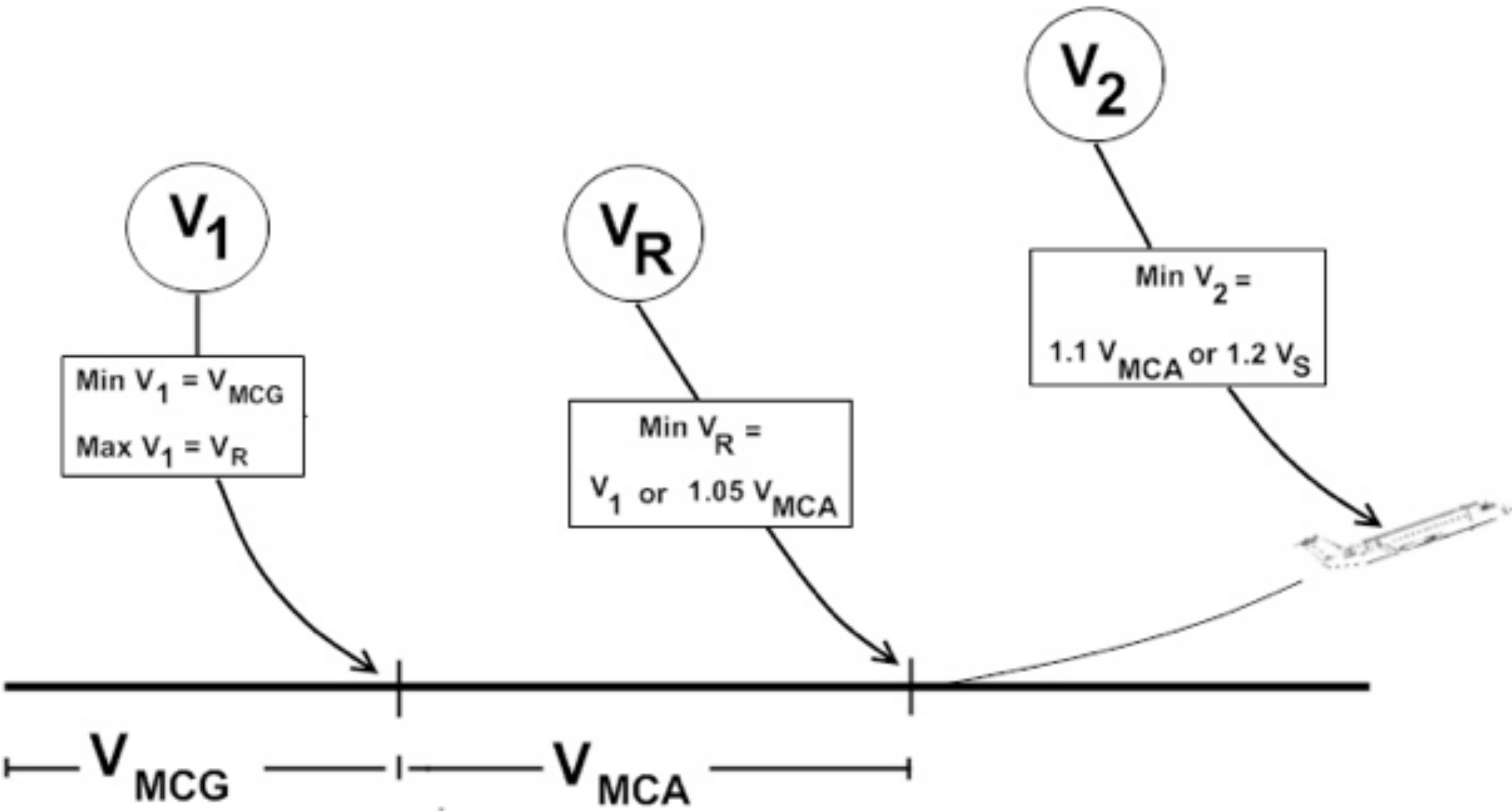
1.1.2 Minimum control speed airborne.

Minimum control speed airborne (VMCA) is determined by essentially the same factors as for VMCG. However, VMCA can be lowered by using a bank angle of up to 5° towards the operating engine.



1.2 Take-off speeds

1.2.1 Take-off speed schedule.



1.2.2 V1.

V1 is defined as the most critical speed for engine failure. At this speed, you must be either in the process of aborting or continuing the take-off. Consequently, V1 must not be less than VMCG.

Normally V1 is so determined that the distance from V1 to stop is equal to the distance from V1 to a point 35 feet above the take-off surface. If so, it is called V1 for a balanced take-off.

1.2.3 VR.

VR is the speed at which rotation for lift-off is initiated. VR must not be less than V1, and not less than 1.05 times VMCA, permitting to reach V2 prior to reaching 35 feet above the take-off surface.

It is very important to rotate the aircraft as close as possible to VR.

A too early rotation will increase the drag, possible to a point where lift-off is delayed, and the ability to clear obstacles is severely affected.

A too late rotation will cause a higher speed than calculated, at rotation. Thus the obstacles may not be cleared with sufficient margin, even if potential performance, as excess speed, is available.

1.2.4 V2.

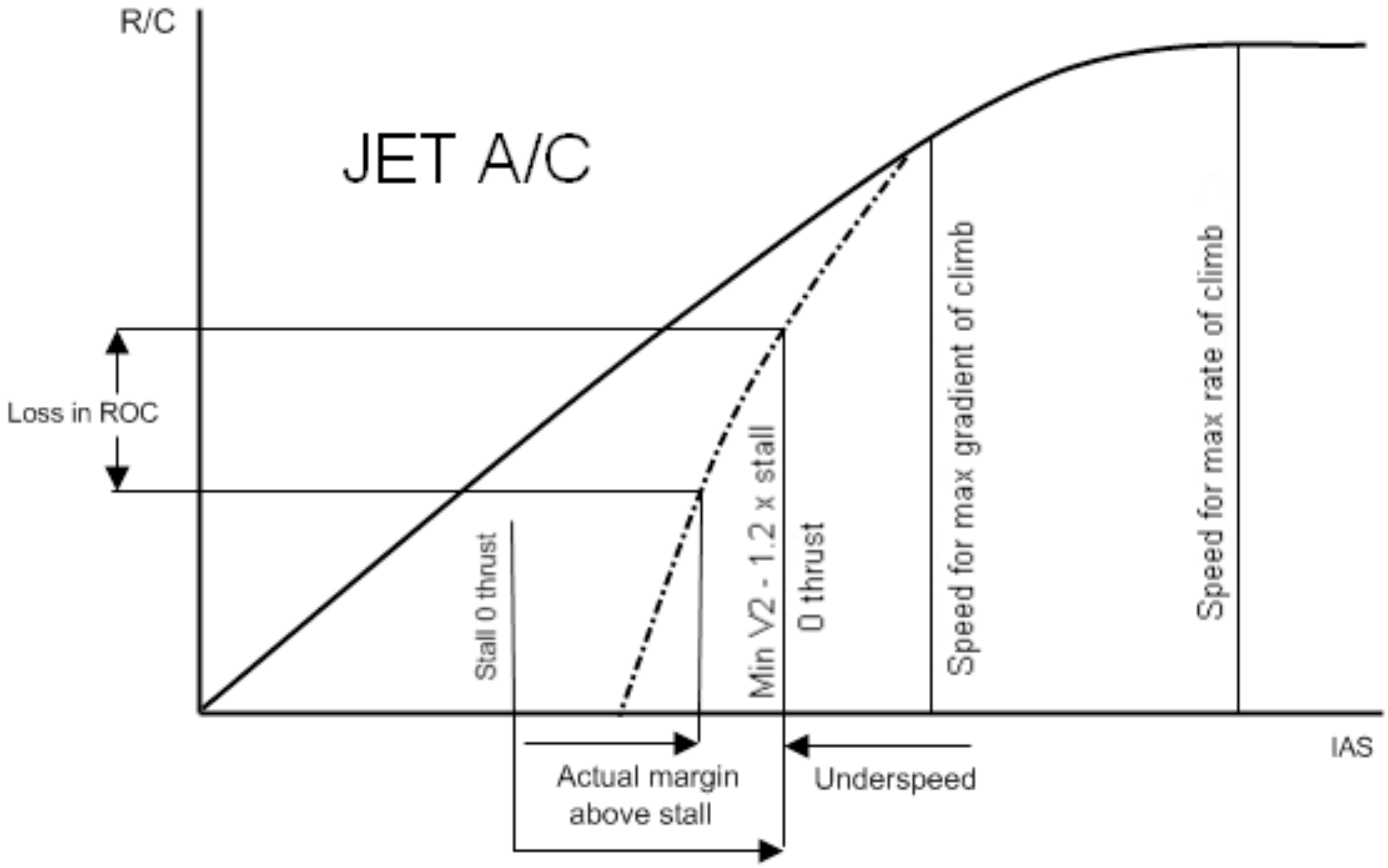
V2 is the take-off safety speed, and minimum speed to be used during initial climb out. V2 shall be at least 1.1 times VMCA, and no less than 1.2 times VS.

V2 is used in determining:

- The required take-off runway length, prior to the end of which it should be attained.
- The climb requirement limitations.
- The obstacle clearance limitations.

V2 should practically be used as climb out speed in case of engine failure, until the aircraft has reached a safe altitude.

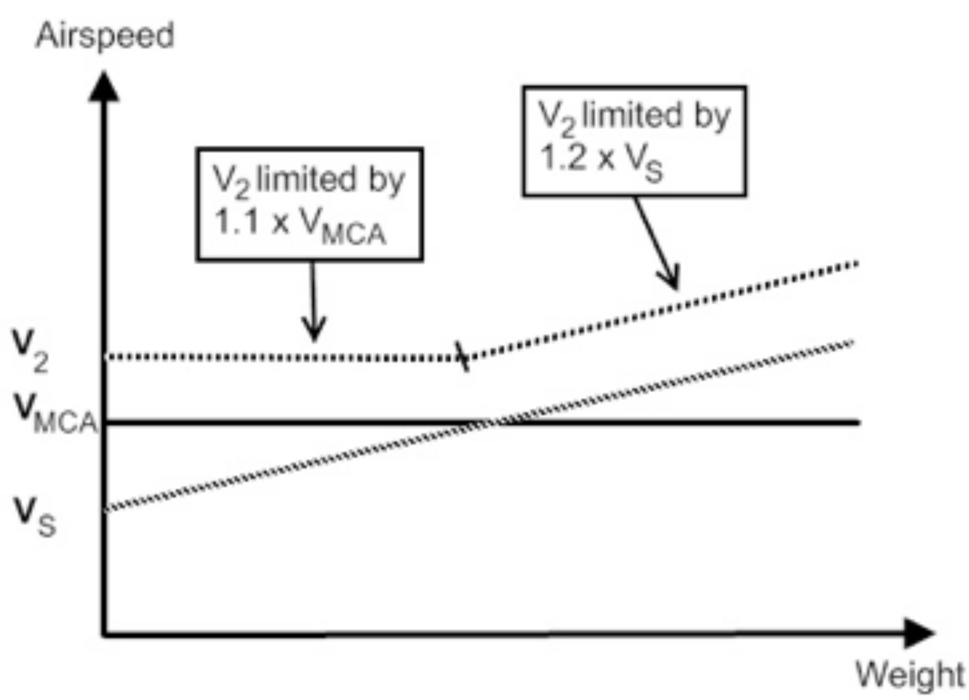
Flying at a speed below V2 will result in a considerable loss in climb performance, as well as creating acute problems regarding stall.



From the above it can be seen that a V2 based on a higher percentage above stall, is an advantage regarding take-off climb requirement. But it will result in a greater runway length requirement.

1.2.5 Minimum V2.

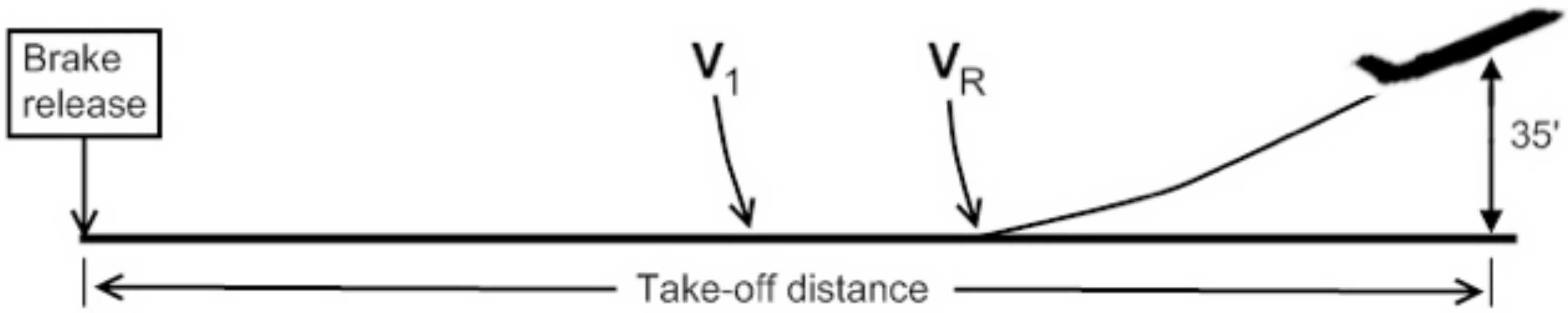
For most aircraft, V2 is restricted by its relation to VMCA at lower take-off weights, and at higher take-off weights, by its relation to VS.



1.3 Runway requirements.

1.3.1 Take-off distance.

Take-off distance is defined as being the distance from brake release to the point where the aircraft attains V2, 35 feet above the runway, with an engine failure at V1.



1.3.2 Accelerate-stop distance.

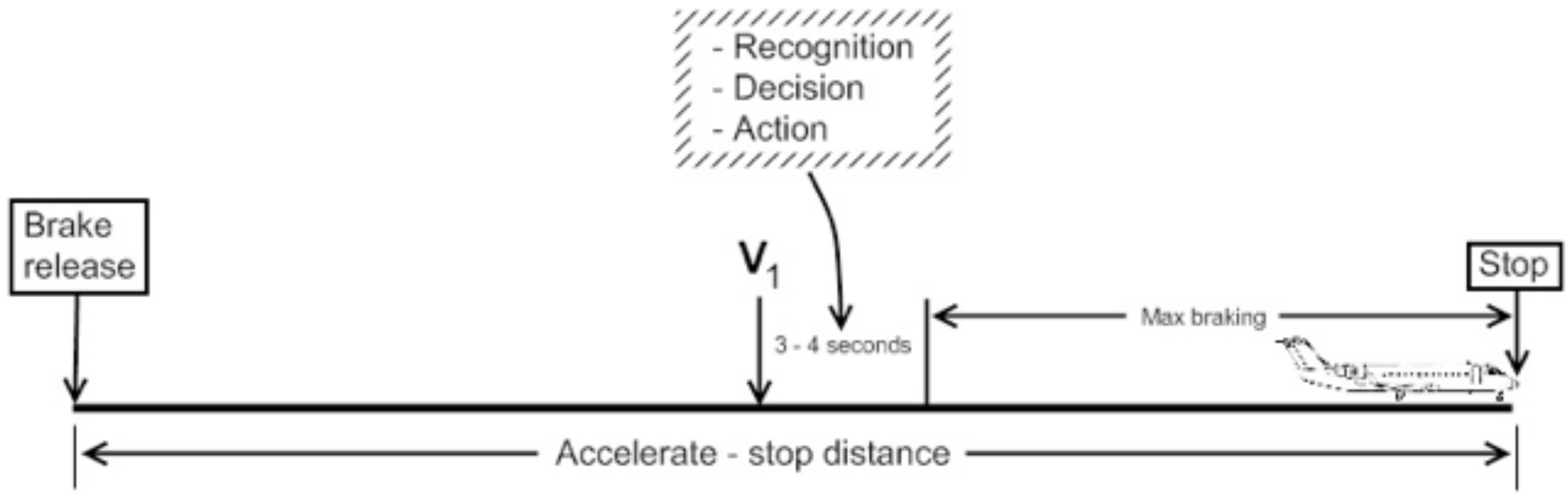
Accelerate-stop distance is the distance from brake release to full stop, assuming engine failure at V1.

In the certification process of a CS-25 aircraft, stopping from V1 is based on the most efficient wheel braking on a dry runway without credit taken from the thrust reversers. However, the effect of reversing on top of maximum efficient wheel braking on a dry runway is very small, whereas CS-25 does allow the effect of reverse thrust to be credited for wet runways, following some specific certification guidelines.

In any case the effect of thrust reversers will actually be used if available.

Furthermore, the reaction time from engine failure to full wheel braking with spoilers extended is assumed to be 3-4 seconds, thus stopping from V1 at a limited runway length is very marginal, especially when the runway is wet, or covered with slush, snow or ice.

If, on the other hand, the engine fails at V1 -10 and the take-off is continued, liftoff may not occur until at the end of the required runway length.

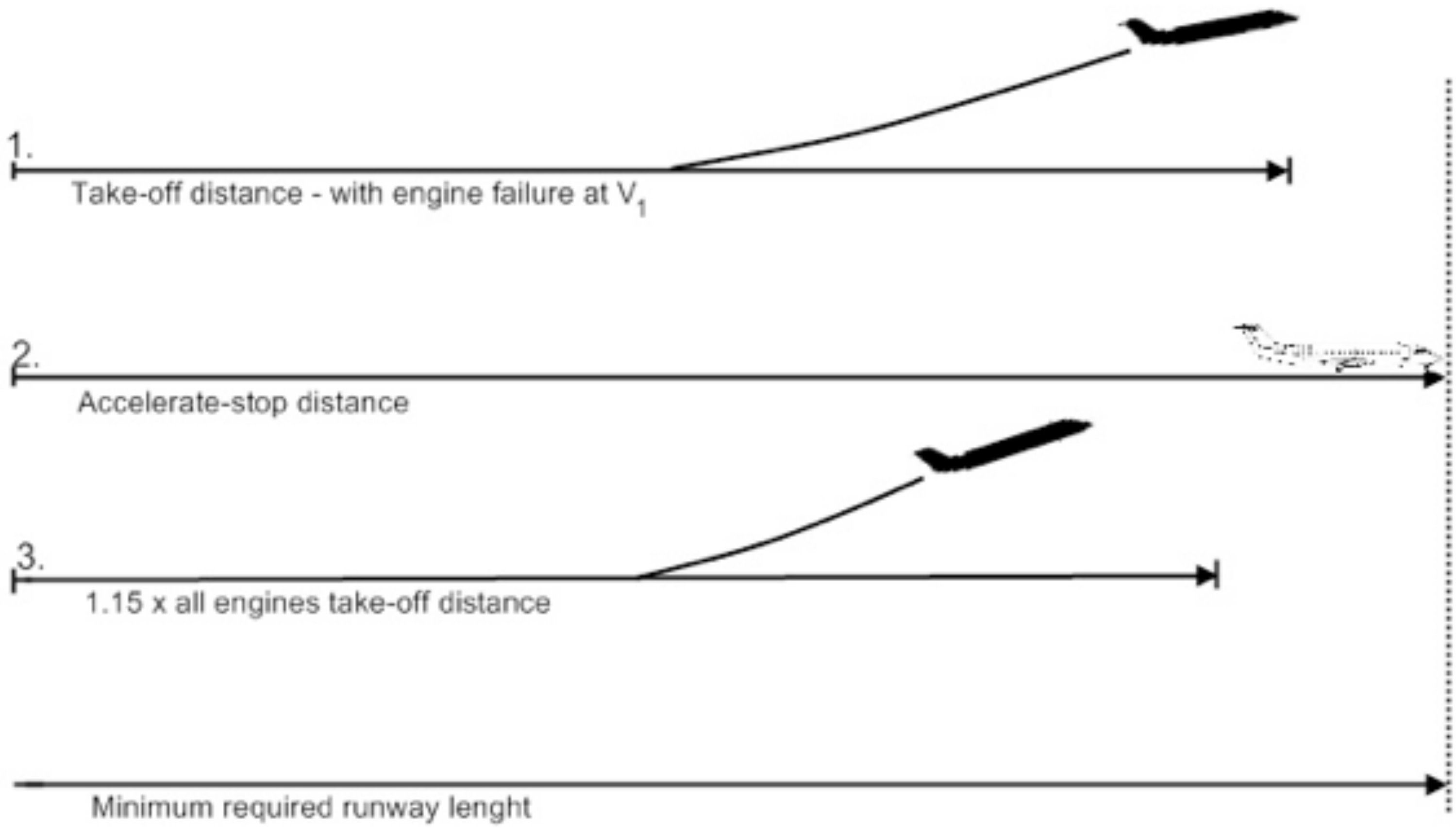


1.3.3 Minimum required runway length.

Minimum required runway length is equal to the longest of the following:

- The take-off distance,
- The accelerate-stop distance, or
- 1.15 times the all engines take-off distance.

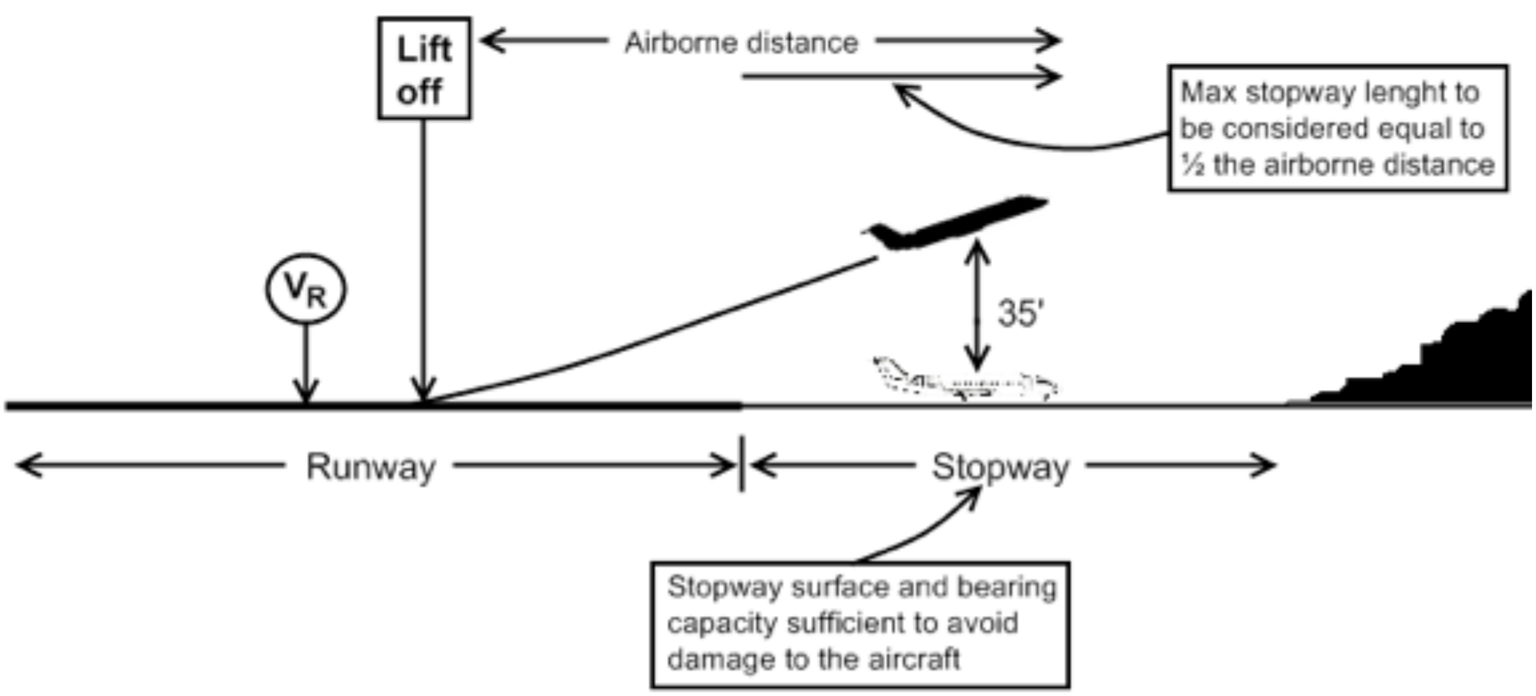
In this example, the accelerate-stop distance is the longest, and is therefore determining the minimum required runway length.



1.3.4 Stopway.

At some runways there may be an area beyond the runway end that is smooth enough, and has enough bearing capacity, to carry the aircraft without damaging it. This area may be used as an additional stopping distance in case of an aborted take-off

The maximum usable stopway is equal to half the distance from lift-off to a height of 35 feet. Consequently, in case of continued take-off, the aircraft will be airborne well before leaving the permanent runway.



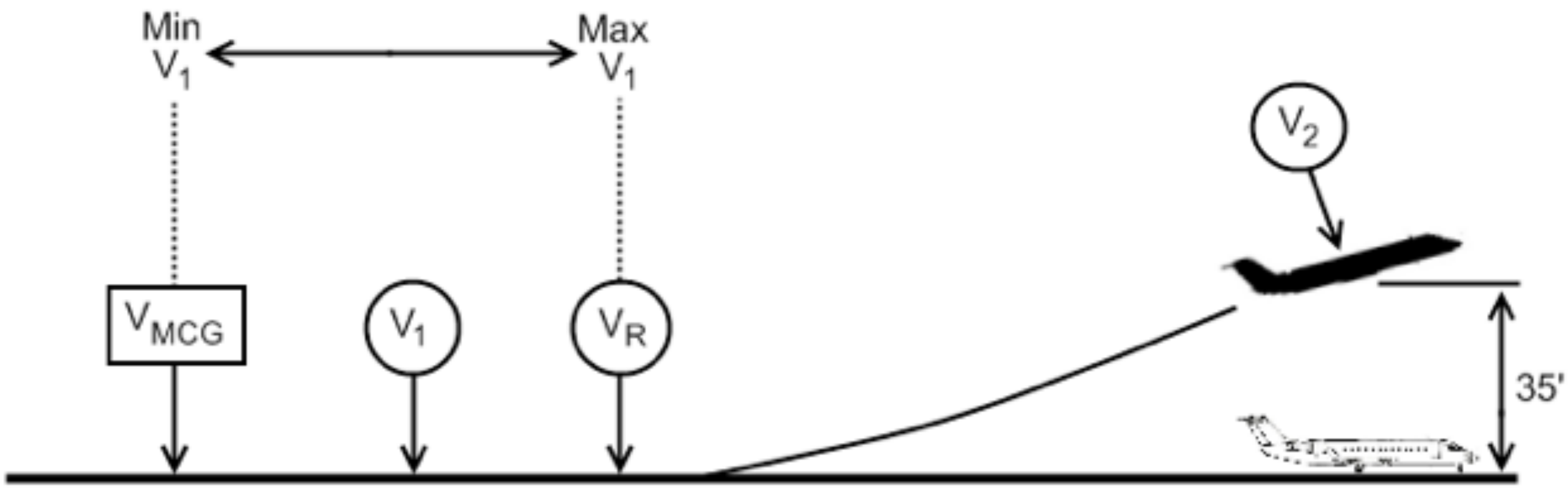
Note:
In fact, we have made a bit of a short-cut here, in the name of simplification.
As we don't practically deal with unbalanced take-off in our daily operation, a specific explanation of the use of clearways is not given in this text.

As a consequence of the balanced take-off concept, a stopway must also satisfy the requirements for a clearway. Therefore, the illustration includes both criteria.

1.4 Balanced take-off.

1.4.1 Balanced take-off

A Balanced Take-off exists when the take-off distance to 35 feet (after engine failure at V1) is equal to the accelerate-stop distance on a bare and dry runway. This balance is achieved by adjusting V1 within the allowed range from VMCG to VR.



The objective of the balanced take-off concept is to obtain the minimum required runway length for a given take-off Mass (TOM), and consequently, maximum TOM for a given runway.

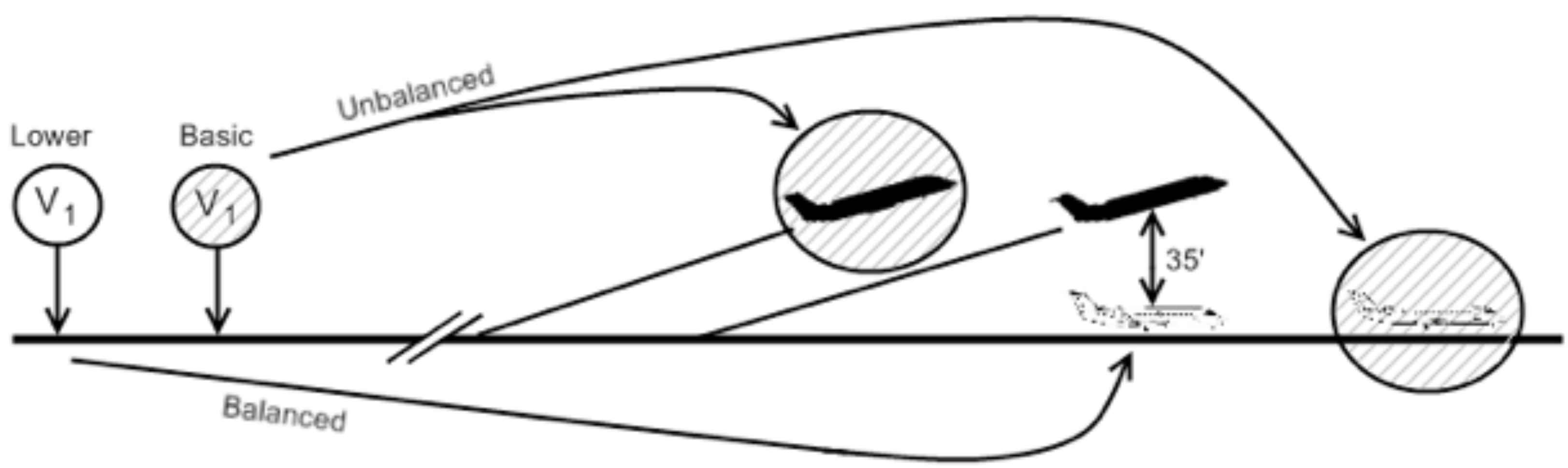
Speeds for the balanced take-off will be calculated by the take-off Data Computer (TODC). To achieve balanced take-off, it is necessary to vary V1 with TOM, slope, elevation, etc.

When the actual conditions are entered in the TODC, the calculation will adjust V1 in order to maintain a balanced take-off. The various conditions that have influence on V1 can be summed up in two categories.

- 1. The conditions that cause Reduced Stopping Capability (slippery runway or downhill slope), or
- 2. The conditions that cause Reduced Acceleration Capability (deposits causing drag, uphill slope, high airport elevation, high temperature).

If V1 is selected in such a way that the distance to stop and 35 feet are unequal, an unbalanced take-off exists. In some special cases this can permit a higher TOM than for a balanced take-off.

1.4.2 Reduced stopping capability.



This illustration shows a case of Reduced Stopping Capability. If the basic V1 were used here, then the accelerate-stop distance would become longer than the take-off distance. So, a lower V1 must be used in order to maintain a balanced take-off.

With the lower V1, the accelerate-stop distance becomes shorter due to less ground speed at brake application, and take-off distance becomes slightly longer due to the prolonged acceleration with one engine failed, from the lower V1 to the same V2.

This illustration shows a case of Reduced Acceleration Capability. If the basic V1 were used here, the take-off distance would become longer than the accelerate-stop distance. Consequently, a Higher V1 must be used to maintain the balance.

With the increased V1, take-off distance becomes slightly shorter due to the prolonged acceleration on all engines from brake release to the increased V1, and accelerate-stop distance becomes longer due to the higher ground speed at brake application.

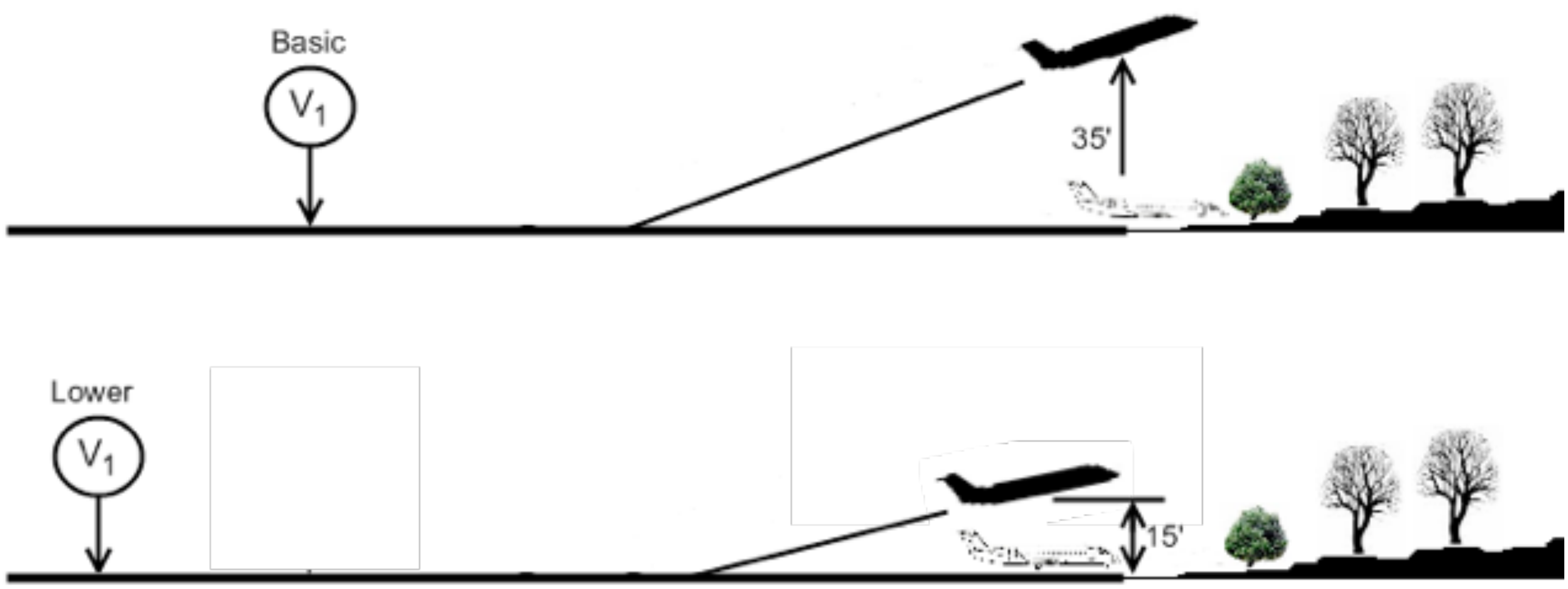
1.4.3 V1 corrections.

In the following we will discuss the effects of a variety of factors that result in corrections of V1.

If the runway is just slippery, i.e. ice covered or wet, and otherwise free from roll resisting deposits such as snow, slush or standing water of 3 mm or more, the case is clear: The considerably reduced stopping capability requires a lowering of V1. Since the acceleration is not affected, nothing calls for a higher V1. Note that minimum V1 is still equal to VMCG.

The real problem with slippery runways is to get a reasonable safety margin in case of an aborted take-off. Therefore the V1 must be reduced, and in order to minimize the weight penalties, V1 is reduced as far down as to achieve balance with a take-off distance to 15 feet only.

In other words, part of the normal safety margin for a continued take-off is converted to an improved safety margin for the aborted take-off.



If the runway is covered with roll resisting deposits such as snow, slush or standing water of 3 mm or more, the problem becomes a bit more complicated.

Slush for instance, creates a large drag during acceleration. The slush drag increases linearly with the depth and approximately with the square of the speed up to 110 – 120 kts, at which speed the drag increase is reduced due to aquaplaning. Additional drag is obtained from the spray from the landing gear hitting the aircraft.

Thus 1.5 cm slush increases the all engine take-off roll by about 20%, 2.5 cm by about 40% and with 5 cm the aircraft will normally not reach rotation speed.

You are facing two problems: Reduced braking capability calls for a lower V1, and at the same time the reduced acceleration capability calls for a higher V1. Consequently, no corrections of V1 should be applied when the runway is covered with roll resisting deposits.

All this will be covered by the TODC calculation. More on contaminated runways in 1.12 “Contaminated Runways”.

1.4.3.2 Runway slope.

A downhill runway means reduced stopping capability and, at the same time, improved acceleration. Both implying a lower V1.

Conversely, a higher V1 must be used with an uphill slope to maintain a balanced take-off.

1.4.3.3 Standard pressure height and OAT.

At high airport elevation and/or at high OAT, thrust output – and thereby acceleration capability – is reduced, while stopping capability is unaffected. This implies a higher V1.

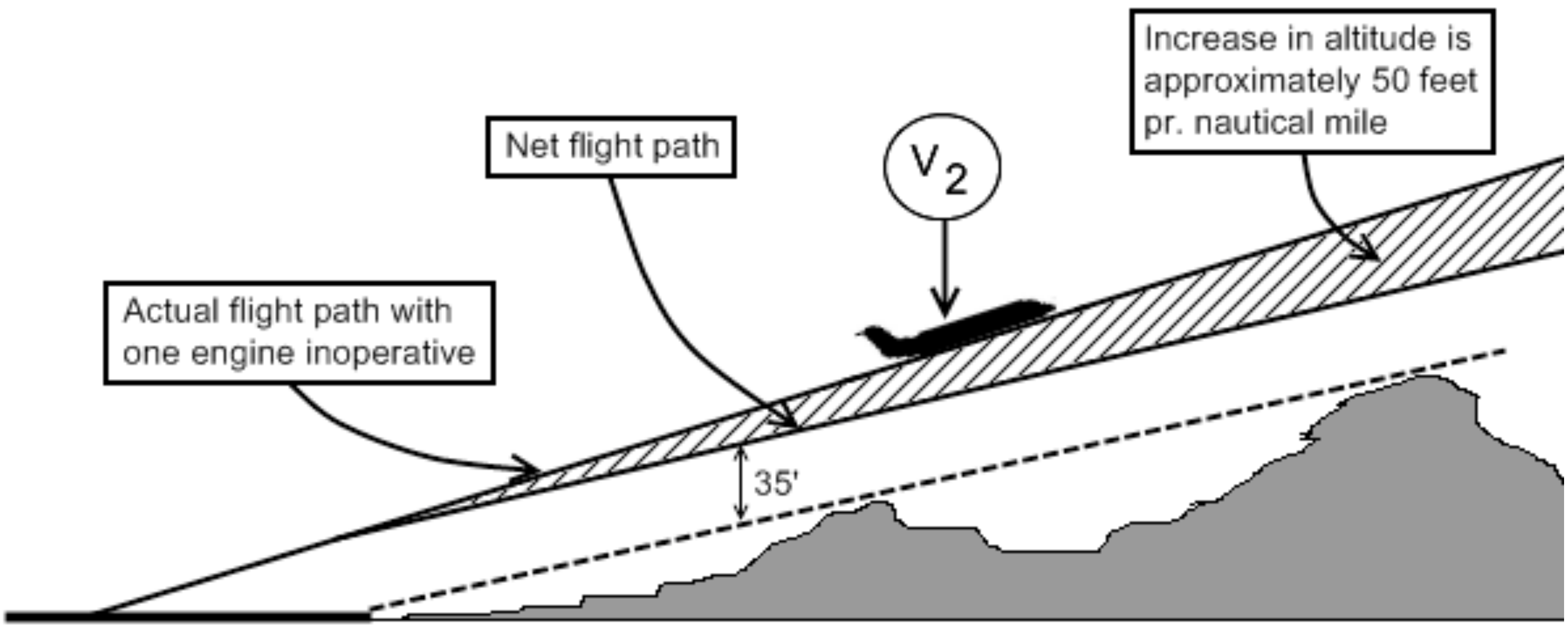
The magnitude of the correction factors vary from one type of aircraft to another. Consequently, the corrections for runway slope, standard pressure height and OAT are not applied for aircraft types, where the effect is negligible.

1.5 Climb out.

1.5.1 Climb out margin

If there are obstacles in the climb out area, the take-off weight must be adjusted in order for the aircraft to clear them with appropriate margin,
after engine failure at V1.

When establishing this margin, we use two different flight paths:
The actual and the net flight path.



The actual flight path is what the aircraft actually should be capable of performing, if flow steadily at exactly V2.

The net flight path is a theoretical flight path, somewhat shallower than the actual flight path. The margin between actual and net flight path, which increases with approximately 50 feet/NM from the runway, is established to allow for small flying inaccuracies and aircraft deterioration.

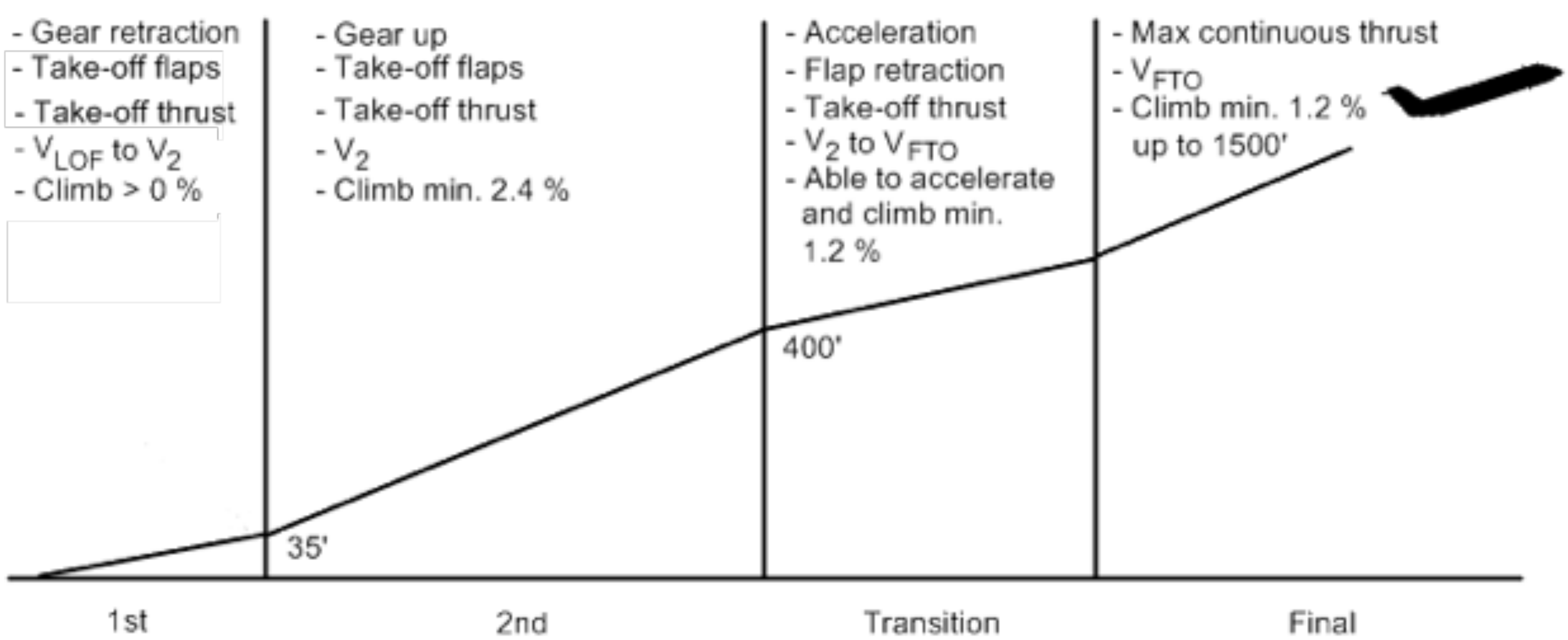
The net flight path must clear all obstacles by 35 feet, within a certain horizontal sector.

In some cases, the Standard Instrument Departure procedure (SID) might not provide adequate obstacle clearance. A specific "Contingency Procedure" is issued, with applicable changes in departure route, altitudes for turns, flap retraction, acceleration and power reduction etc.

1.5.2 Climb out requirements.

Even if there should be no obstacles in the climb out area, the aircraft must still have a certain Manoeuvring Capability to climb accelerate or turn, with one engine inoperative. Thus, even if an unlimited runway without obstacles is available, the take-off weight may be limited by the below requirements.

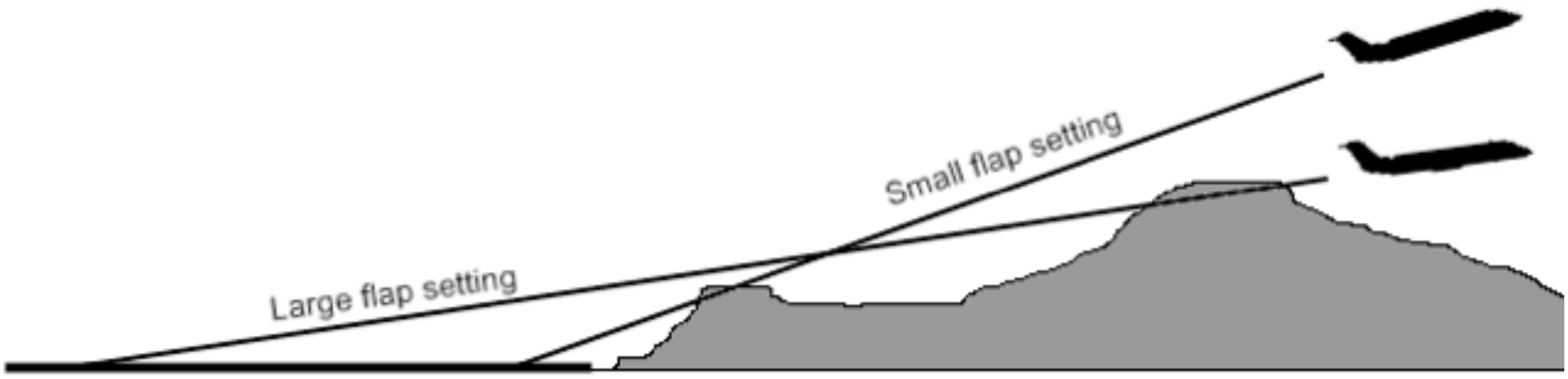
The way we meet this requirement is by adjusting the take-off weight to the so-called Climb Requirement Limited Weight. The required climb capability varies for 2- 3- and 4-engined aircrafts.
The average corresponds to a climb rate of approximately 500 feet pr minute. Note that this is a separate Manoeuvring Requirement with no relation to obstacle clearance. In order to distinguish between obstacle clearance and climb requirements, just imagine how a sufficient headwind component might help you to clear the obstacles in the climb out area, while it will have no influence on your Rate of Climb For establishment of the required gradients, the take-off climb is divided into four segments. The second segment is practically always the limiting one.



1.6 Optimum take-off flap setting.

1.6.1 Short runway and/or obstacles

The optimum flap setting for take-off is the one resulting in maximum allowed take-off mass for the actual conditions.



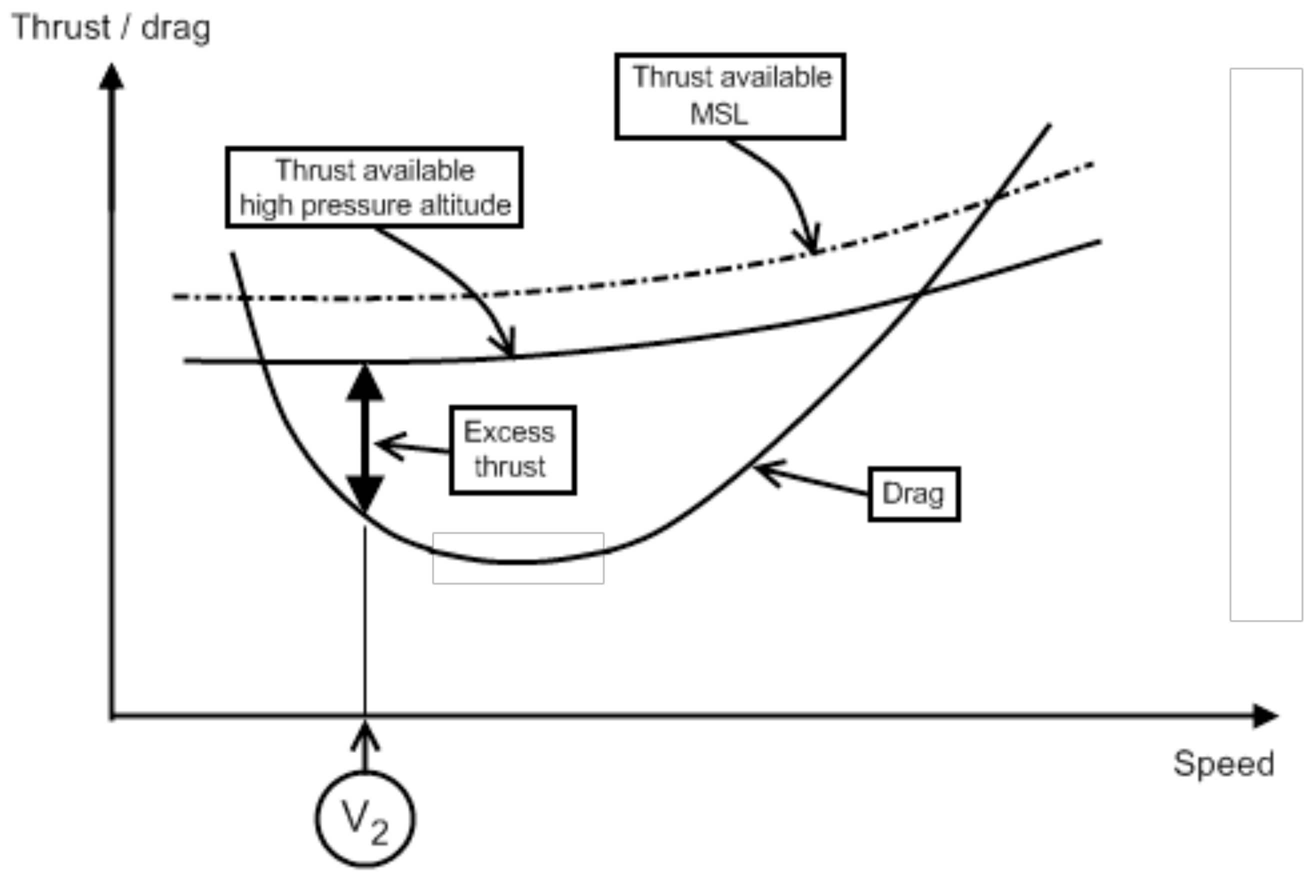
For take-off on a short runway, the larger flap setting will give you maximum take-off mass versus runway length, while it might adversely affect your ability to clear obstacles or meet the climb requirements.

If there are no obstacles in the climb out area, the optimum flap setting depends on the height of- and the distance to the obstacles.

1.6.2 High elevated airport and/or high OAT.

For take-off on a high elevated airport and/or at high OAT, the take-off mass will often be limited by climb requirements.

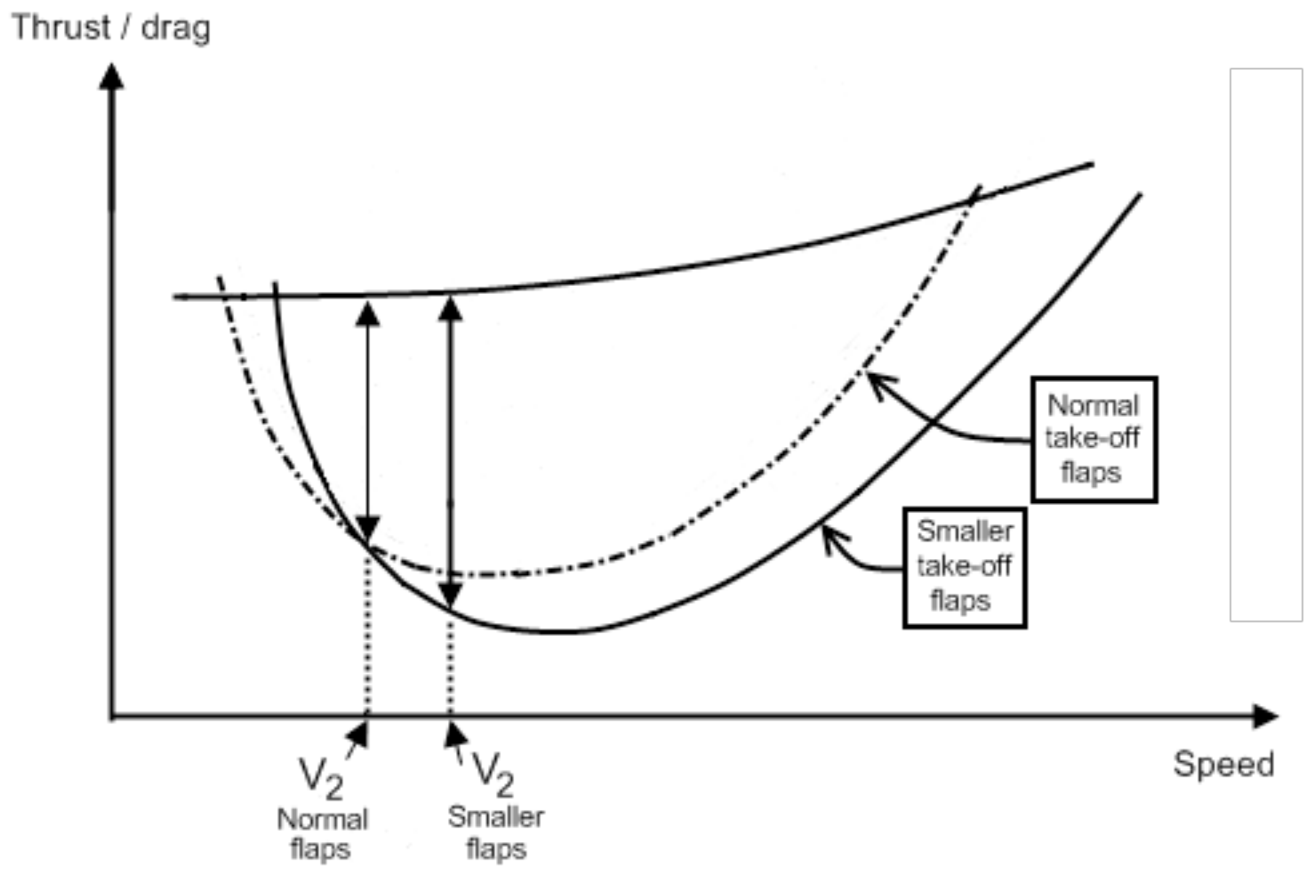
The problem with climb requirements is to obtain the required climb – or manoeuvring – capability in the second segment, i.e. to operate with a sufficient amount of Excess Thrust.



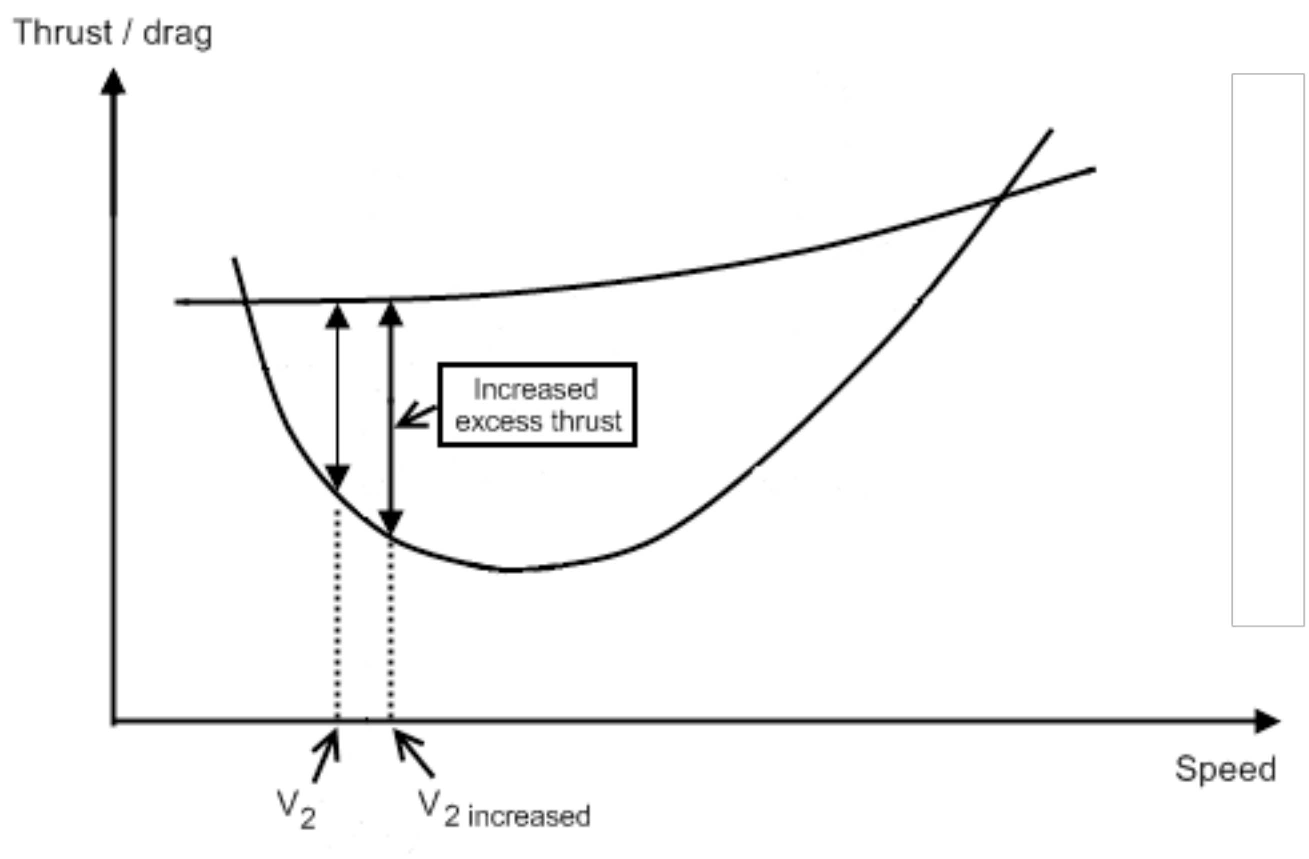
1.6.3 Drag.

As you cannot change the thrust rating of the engine, the only way to obtain sufficient excess thrust is to reduce drag. There are two solutions to the problem of reducing drag in the second segment. The normal solution is to choose a lower flap setting for take-off.

The consequence with respect to excess thrust is illustrated below.



Another way to reduce drag is to operate with a higher V2.



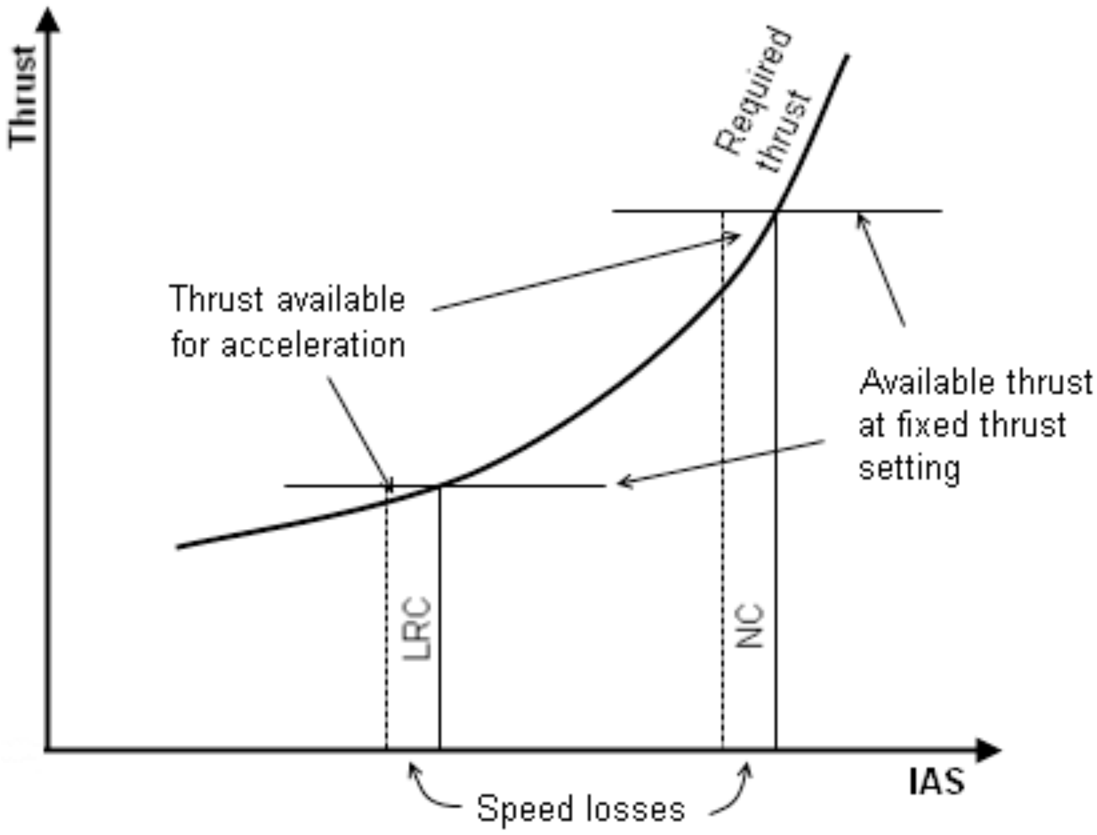
When this solution is applicable, it will be considered as a standardized V2 of more than 1.2 times VS.

1.7 Speeds and En-route limitations.

1.7.1 Max operating limit speed and Mach no.

VMO / MMO is limited by structural requirements (VMO) and high speed aerodynamics (MMO). This is the max operational speed and must not be exceeded.

1.7.2 Cruise speed stability.



The flatter the slope in the above graph, the lower the speed stability. In the flat slope range, a small increase in drag due to turbulence, people moving around or thrust loss, means a large decrease in speed. At the same time, the available thrust to accelerate the aircraft is very small for a given thrust setting. It is impossible to state the minimum speed for cruise stability, but generally it is 10-15 kts below LRC.

Planning and flight at speeds below cruise stability should be avoided.

1.7.3 Buffet onset speed

There are two buffet onset speeds. Low speed buffet and high speed buffet.

The two buffet speeds both come from related but somewhat different conditions:

The low speed buffet, or stall buffet, is related to the effect of Mach number reducing the maximum lift capability of the wing. That means that the stall buffet speed will increase with increasing altitude, provided the speed is in the Mach region affecting the maximum lift capability.

The high speed buffet is related to the growth of shock waves on the wing and the turbulent air flow associated with shock movement.

1.7.4 Stall speed (VS)

Stall speeds provided by the manufacturer are normally based on:

- Engine idling at zero thrust (negligible effect on stall speed)
- Centre of gravity in the most unfavourable position (forward)
- Aircraft trimmed for straight flight at speed between 1.2 and 1.4 times VS.
- The approach to stall made with an elevator position resulting in a speed reduction of maximum 1 kt/second.

The stall speed increases with increasing air load supported by the wings.
The stalling speed will increase with:

- Increasing gross weight.
- Increasing vertical acceleration, obtained for instance in a goaround, a turn, upwards vertical gust etc.
- Forward CG compared to aft CG. Normally there is a negative load on the horizontal tail. With a forward CG this negative load as well as the required lift of the wing increases. This increases the drag and the stalling speed.
- Ice on especially the upper wing surface resulting in a less efficient airfoil with reduced lift capability, increased gross weight and increased drag.

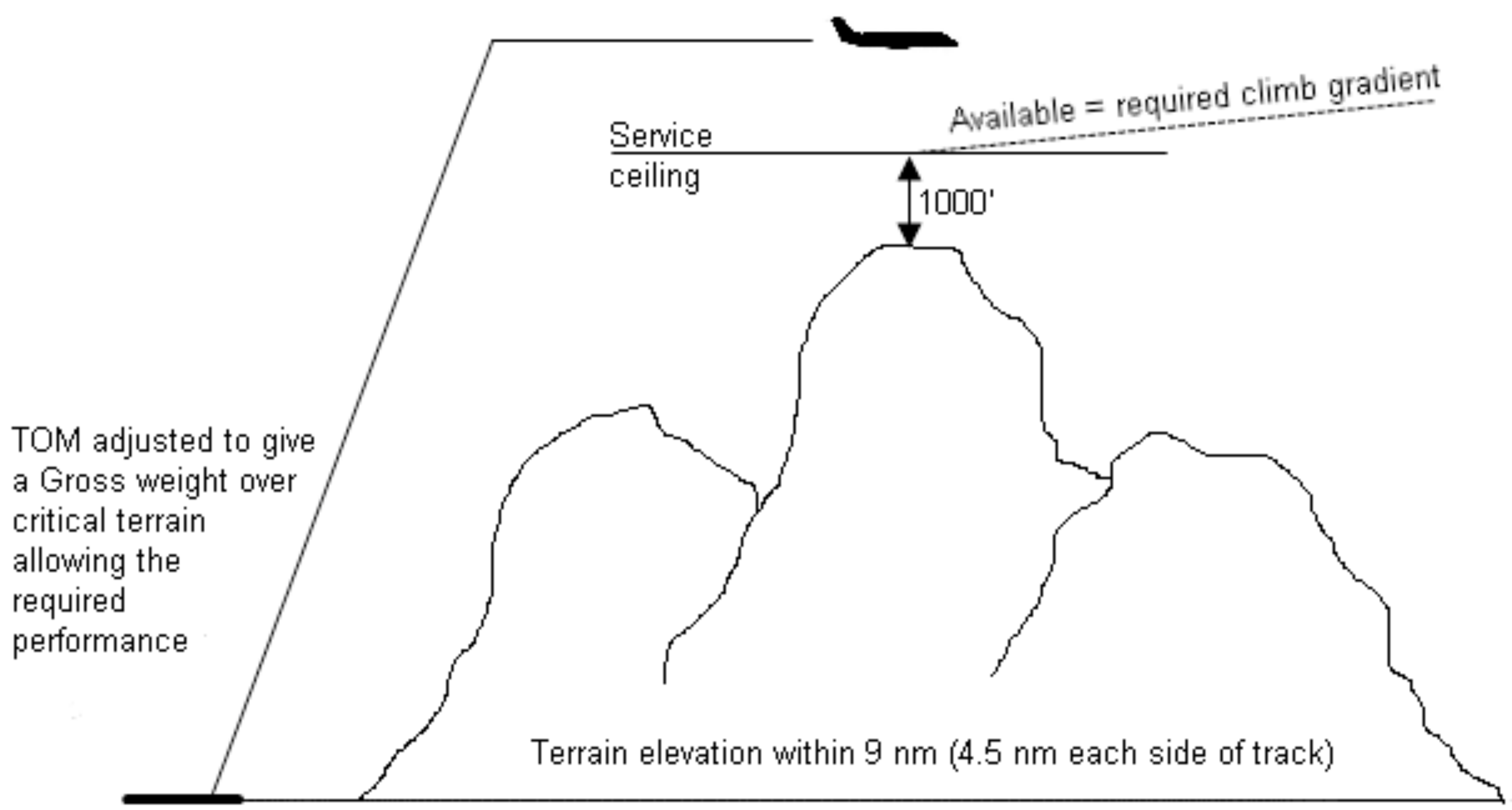
1.7.5 Terrain limitations.

In order to ensure a safe flight over mountainous terrain, the flight must be planned in such a way, that in case of an engine failure, the aircraft can clear the most critical terrain with acceptable safety margins. This can be obtained by:

• Gross weight limitations permitting the aircraft to retain sufficient climb performance above the terrain. (Service ceiling), or
• Laying down minimum altitudes, high enough to permit the aircraft to overfly the terrain during altitude loss (drift-down)

1.7.5.1 Service ceiling.

The service ceiling is equal to the altitude at which the aircraft in still air can perform a performance required climb gradient with an AFM defined normal climb speed, operating engine at MCT, and gear and flaps retracted.



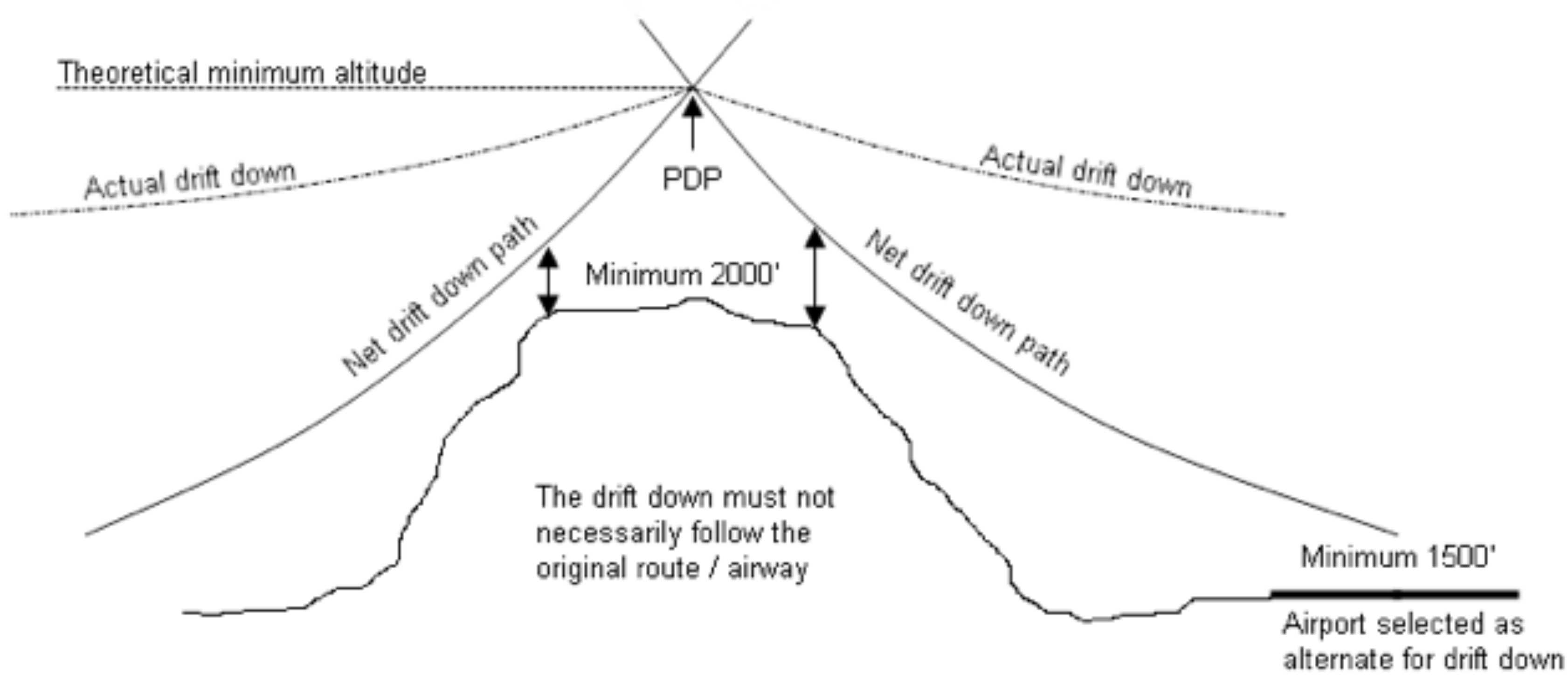
The 1 engine service ceiling required climb gradient for a 2 engine aircraft is 1.1%.

1.7.5.2 Drift-down procedure.

Drift-down is an alternative to the service ceiling requirement, and basically means that the aircraft must enter the airspace above the critical terrain, at an altitude high enough to clear the terrain on track to the nearest alternate, or airspace with no terrain restrictions, following an engine failure.

This must be met with the following margins:

- • The drift down path used in the calculations, must at each point be based on a descent gradient equal to the actual gradient minus the required service ceiling gradients. The drift down path is called the Net Drift Down path.
- Vertical clearance between terrain and net drift down is no less than 2000 feet.
- The critical points for start of drift down must be stated as a predetermined point – PDP.



1.8 Landing requirements.

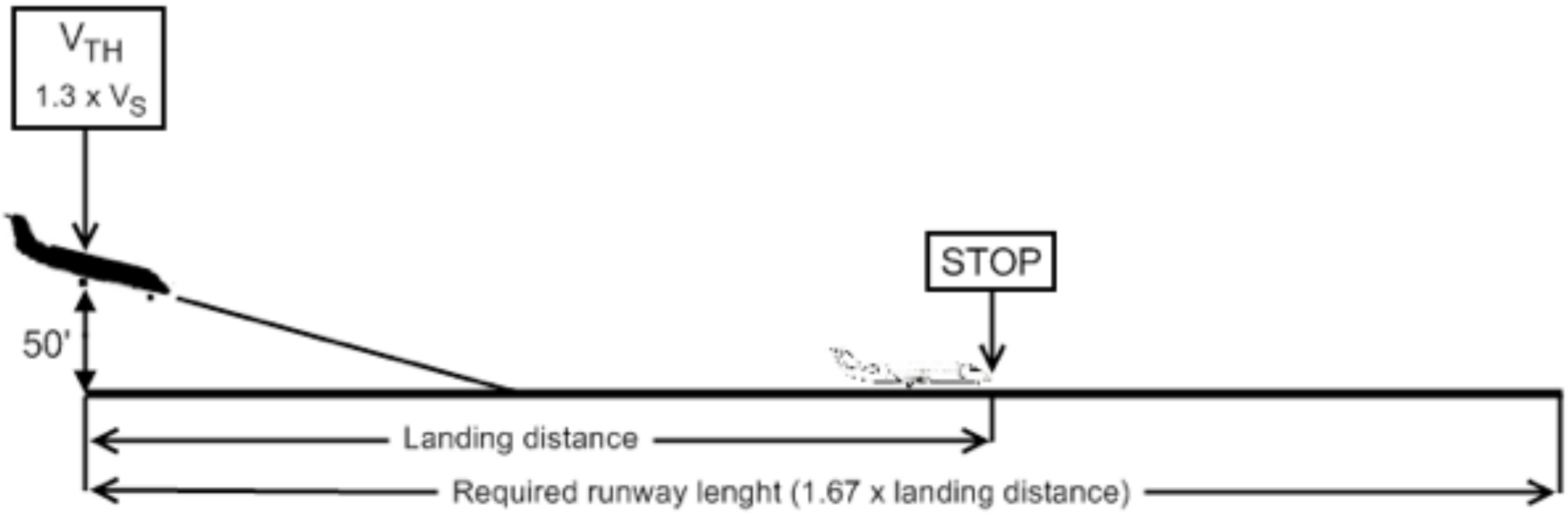
1.8.1 Landing weight.

The maximum landing weight is limited by one or more of the following requirements and limitations:

- Runway length
- Obstacles in the approach area
- Landing climb requirements
- Structural landing weight

1.8.2 Landing distance.

Landing distance is the distance from 50 feet height over the runway threshold to complete stop.



Landing distance must not be more than 60% of the available runway, i.e. Required Runway Length is equal to 1.67 times landing distance.

If more than one corrective factor is to be used, to obtain the landing distance, all the factors must be multiplied.

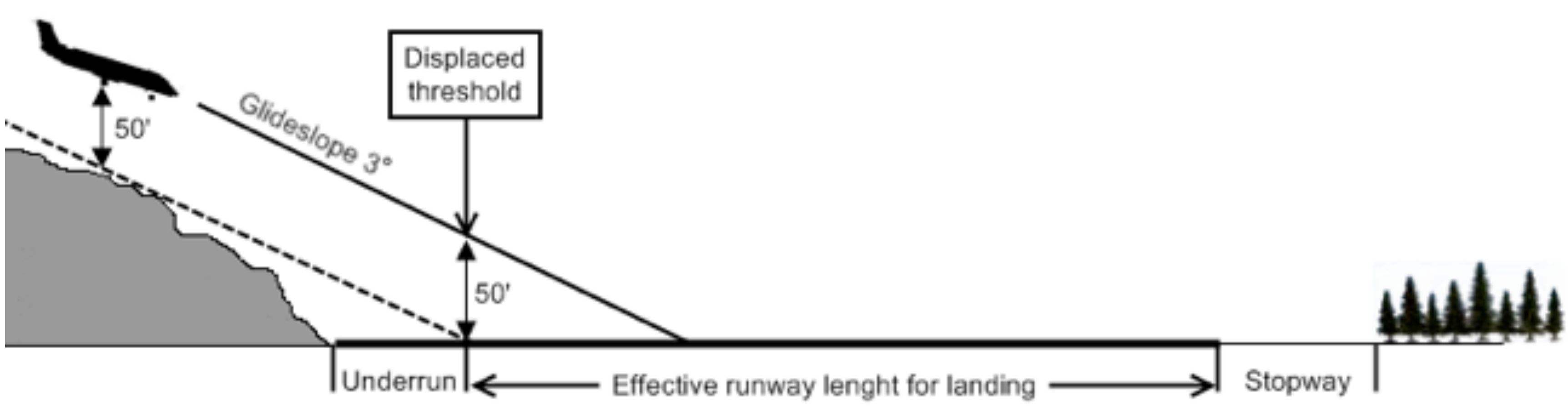
Factors increasing the landing distance are:

- Increasing landing weight.
- Contaminated runway surfaces.
- Downhill runway slope.
- High airport elevation, due to lower air density.
- Tailwind.
- High temperature, due to lower air density.
- Reduced flap setting.
- Failure of ground spoiler system.
- Failure of anti-skid system.
- Faulty thrust reverser system (if used in LD calculation)

1.8.3 Threshold.

VTH is equal to 1.3 times VS for the given landing configuration.
It is used in the landing runway length calculation from 50 feet above the runway, and is the recommended speed over the runway threshold.

If there is high terrain in the approach area, the threshold may be displaced to assure adequate terrain clearance (50 feet) when following a normal glide slope of 3°.



Displaced thresholds may also be caused by other factors, such as noise sensitive approach area, ground activities close to the runway etc.

The part of the permanent runway situated before the displaced threshold – Underrun – and may used for take-off.

If there is a Stopway at the end of the runway, it must not be used in connection with landing weight calculations, unless the Stopway is of runway quality.

1.9 Pull-up capabilities.

According to the requirements, the aircraft must be able to maintain a specified minimum climb performance in case of a discontinued approach, in both approach and landing configuration.

Both requirements are manoeuvring requirements, so even if an unlimited runway length is available, the lower of the two requirements can still limit the maximum landing weight for a given runway.

Based on this, two problems arise:

1. Obstacle clearance, and
2. Manoeuvring capability.

Obstacle clearance is covered by the official minimum altitude in combination with the specific Missed Approach Procedure, stated on the approach plate for a given runway.

1.9.1 Landing climb.

Manoeuvring capability is covered by the Landing Climb Requirement.

The landing climb requirement is based on:

- Landing flaps
- Gear down
- All engines at go-around thrust

Basically, the landing climb requirement only covers the short period of flight time taking place at minimum altitude.

The landing weight is rarely limited by the landing climb requirement. The problem may arise only at high elevated airports in hot climates. Landing climb requirement for a 2 engine aircraft is 3.2%.

1.9.2 Approach climb

To ensure manoeuvring or pull-up capability in case of landing with one engine inoperative, the Approach Climb Requirement is valid

The approach climb requirement is based on:

- Approach flap setting
- Gear up
- One engine out, and other(s) set to go-around thrust

Especially for two engine aircraft, the approach climb requirement will limit the flap setting used for approach with one engine inoperative. The problem is covered by specific flight procedures valid for the approach and landing on one engine. Approach climb requirement for a 2 engine aircraft is 2.1%.

1.9.3 Go around.

There is no obstacle clearance requirement with regard to go-around in the performance requirements. However, obstacles in the missed approach sector are considered in calculation of landing minima i.e. climb out with one engine inoperative must clear all obstacles in the missed approach area with certain margins.

Go-around from altitudes below minima or after decision point may not always provide terrain clearance, even with all engines operating, when following the published standard missed approach procedure. Especially if the maximum permissible landing mass is higher than the maximum permissible take-off mass, for the same runway.

1.10 Malfunctions.

The runway length requirement (1.67 x landing distance) is applicable for Flight Planning.

If a technical system such as ground spoiler extension or anti-skid should be inoperative prior departure, the maximum landing mass must be adjusted as required to keep the landing distance within 60% of available runway length.

If the malfunction should occur after take-off, the commander will decide which margins he needs, and select the most suitable runway for landing.

1.11 Structural requirements and limitations.

1.11.1 General.

All aircraft structures are designed for the anticipated load that may be caused by manoeuvres performed by the pilot, or by flight through disturbed air, which for most transport aircraft will be the major design consideration, since they do not need to be violent manoeuvred.

Reasonable figures for gust velocities, in relation structural design requirements, have been established. Even so nature are still able to produce forces exceeding these figures.

To protect the aircraft, operational limitations regarding weight, fuel distribution and speed are derived. It is anticipated that the pilot will operate within these limitations, and avoid areas of extreme turbulence.

1.11.2 Load factors.

1.11.2.1 General

The load factor can be defined simply as the ratio between the total air load on the wing and the weight of the aircraft.

In un-accelerated flight, gravity will act on the aircraft with a force of 1 g.
T
he load factor exceeds 1 in manoeuvres like go-around and turns. The harder the manoeuvre the lager is the resulting load factor.

In a turn the load factor can be calculated by dividing 1 by co sinus for the angle of bank. For a 45° bank turn, the load factor is 1.4. For 60° it is 2, and for 75° it is 3.9.

When an aircraft encounters a gust, a change in lift and wing loading will be caused by the abrupt change in angle of attack. An up-gust increases the load factor, and vice versa.

There are two load factor limits defined Limit Load factor and Ultimate Load factor. Between them is a Safety factor. Thus, Limit load factor times Safety factor equals Ultimate load factor.

The below mentioned design load factors are upward acting (positive).

Heavy negative loads are less usual on transport aircraft, and the positive loads are normally responsible for the limits established to protect the aircraft structure.

1.11.2.2 Limit load factor

The limit load factor is the highest load factor which can be absorbed by an aircraft without permanent deformation of any parts of the construction.

Generally for transport aircraft the limit load factor must not be less than 2.5 with flaps up, and no less than 2.0 with flaps extended.

1.11.2.3 Ultimate load factor

The ultimate load factor is the highest load factor which can be absorbed by an aircraft without failure of any component of the structure.

As the safety factor normally is equal to 1.5, the ultimate load factor for the structure will be 3.75 with flaps up, and 3.0 with flaps extended.

1.11.2.4 Safety factor

The safety factor is different for the various aircraft components, and depends on material and working methods used. Normally the minimum safety factor is 1.5.

1.11.3 Speed limitations.

1.11.3.1 General.

Establishing speed limitations on an aircraft is rather complicated, and the following will be a simplified explanation to this.

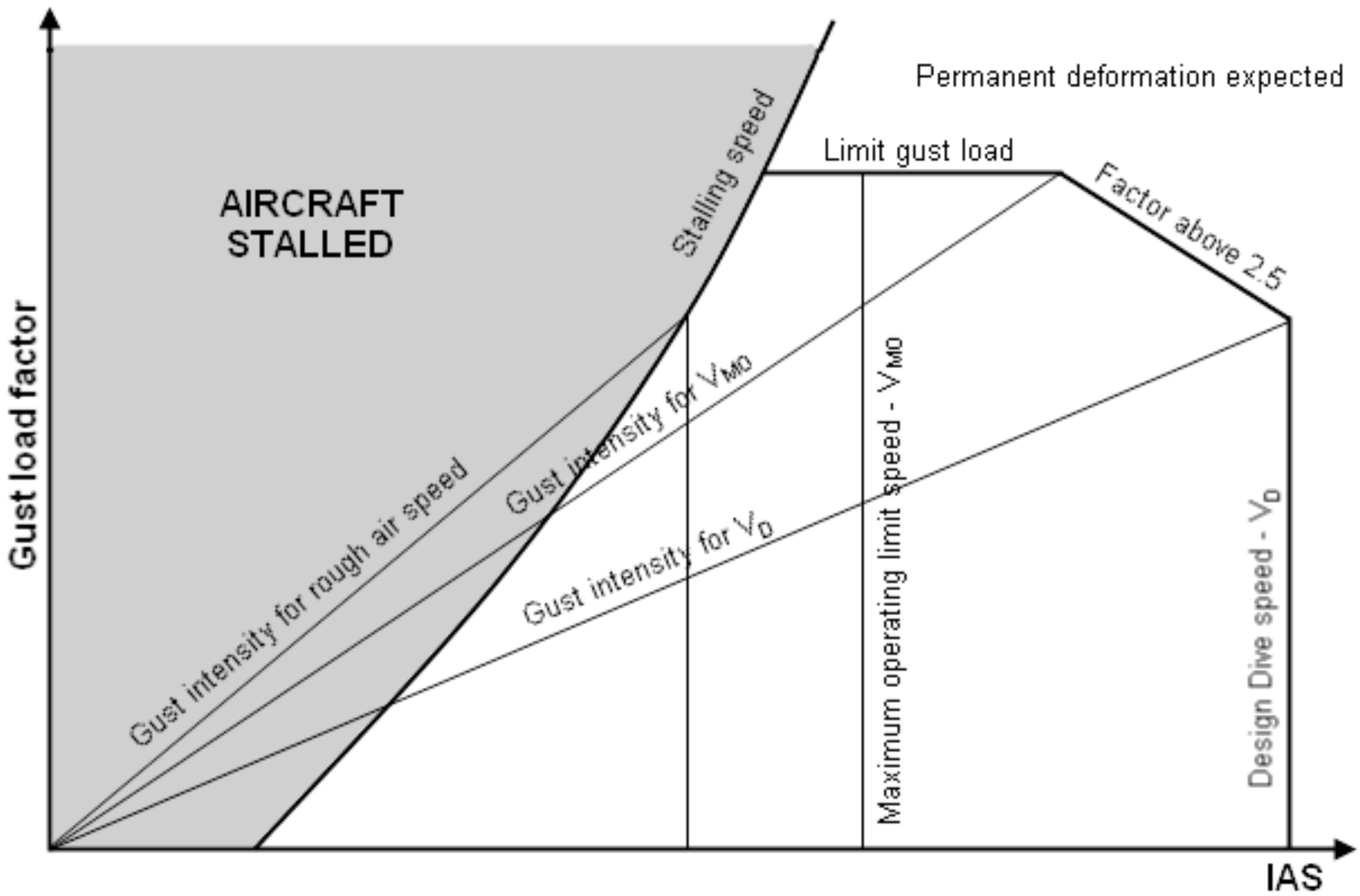
Generally there are two requirements limiting the maximum speeds:

- The aircraft must be able to withstand certain gust intensities without permanent deformation. These limitations are called “max” speeds, for instance VMO, and represents maximum speeds at lower altitude. At these altitudes the maximum speeds are normally constant or increasing slightly with altitude.
- The aircraft must not show any irregularities with regard to control forces, control effectiveness and stability. This can be expected when the aircraft approaches higher Mach numbers and is caused by changes in airflow around the aircraft. The result is limiting Mach numbers, for instance MMO, and represents maximum speeds a higher altitude. At theses altitudes the maximum speeds are given as constant or slightly varying Mach numbers. The corresponding IAS will decrease with increasing altitude.

The Mach number limits are chosen by the manufacturer, whereas the “V” speeds are established according to required intensities and gust load factors.

The gust load factor takes into account, both the lift/gross weight ratio, and the mass force acting on an aircraft in turbulence.

The limit gust load factor is a function of aircraft geometry, aircraft speed, gust velocity, gross weight and altitude. It must not be lower than the limit load factor.
All speed limitations must be determined for the most critical combination of altitude, gross weight and fuel load. From the figure below, it can be seen that the aircraft can withstand higher gust velocities at lower speeds, and that the stalling speed increases with increasing gust velocity (g-stall)



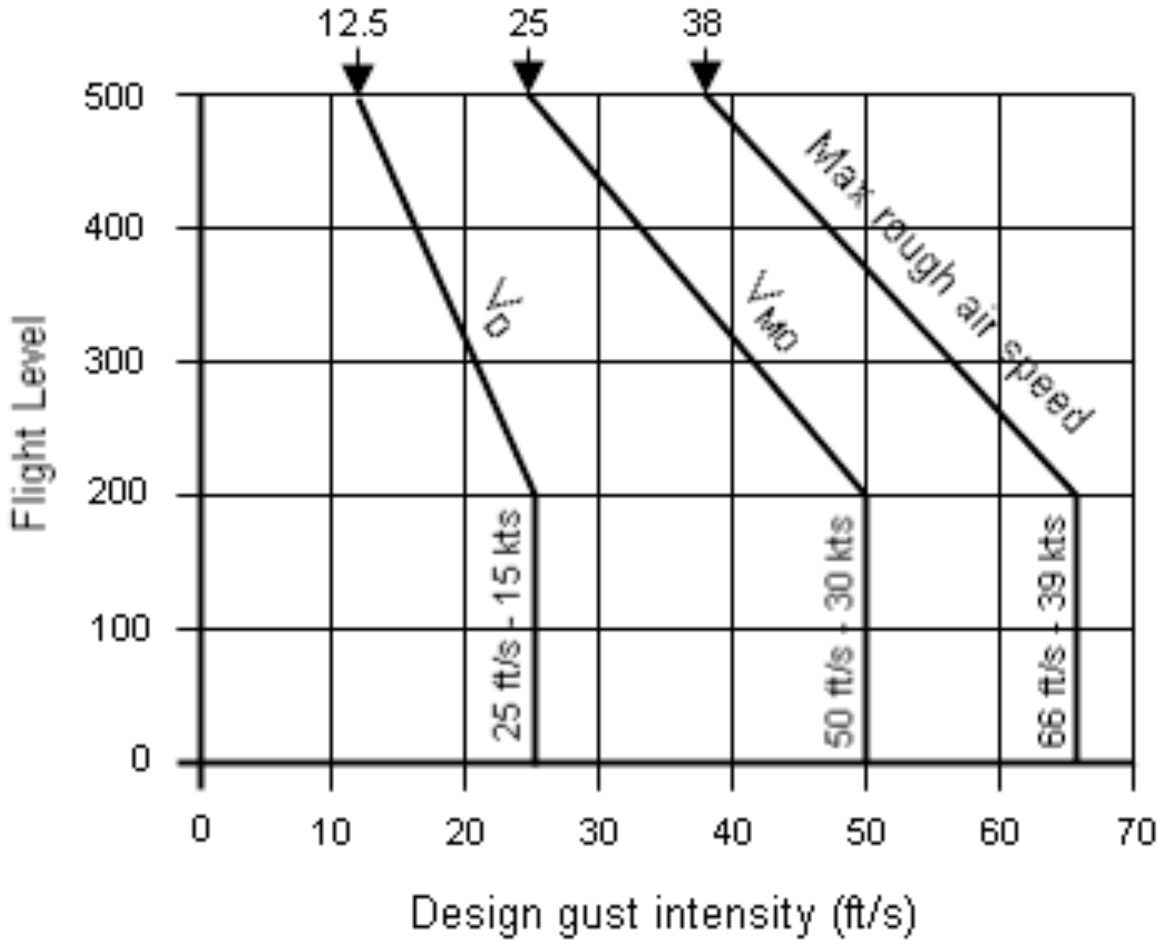
1.11.3.2 Design Dive Speed VD/MD.

VD/MD is a speed used only for design and certification demonstration, and is higher than any speed used in airline operation.

It is defined as the lower of the following:

- The speed at which the aircraft can encounter a gust intensity of at least 25 ft/s (decreasing above FL200) without exceeding the limit gust load factor.

- The Mach number (MD) up to which it is demonstrated that noundesirable flight characteristics occur, except moderate buffeting.



1.11.3.3 Maximum Operating Limit speed VMO/MMO.

This is the maximum permissible speed in airline operation and should not be deliberately exceeded in any regime of flight.

At VMO the aircraft can encounter a gust intensity of at least 50 ft/s – below FL200 – without exceeding the limit gust load factor. Following flight tests it must be demonstrated that VMO/MMO is at least 20% below VD/MD, and therefore practically impossible to inadvertently exceed in normal operation.

1.11.3.4 Recommended Rough Air speed.

Rough air is referred to, as a condition where the pilots' main concern lies with the safety of the passengers and aircraft.
In selecting this speed, a compromise must be made between the following two limitations:

- A low speed to permit the structure to withstand the greatest possible gust velocities.
- A speed high enough to prevent an accelerated stall caused by gusts associated with the turbulent air.

The Rough Air speed meets the limitations of a gust intensity of at least 66 ft/s – below FL200 – and generally there is little risk of encountering this, except perhaps inside storm cells.

1.11.3.5 Speed reduction in rough air.

The effect of turbulence is decreased with decreased speed. This is done by reducing thrust, or using the speed brakes, and not by increasing pitch since it will produce an additional g-acceleration, thus increasing the load factor.

1.11.3.6 Use of flaps in turbulence en route.

He flaps are intended as approach and landing aids only. As the gusts at approach altitudes are of reduced intensity, and due to the low probability of encountering extreme gusts during the limited time in approach conditions, the extended wing flaps are designed accordingly.

With flaps extended the aircraft must be able to encounter a sharp edged gust of at least 25 ft/s (15 kts) without exceeding the limit load factor of 2.0.

1.11.3.7 Landing gear position in turbulence en route.

The landing gear can be extended to obtain a lower airspeed caused by the increase in drag. However, some other aerodynamic and performance considerations must be addressed in this situation, especially at high flight levels, were as the gear preferably must be retracted.

1.11.3.8 Conclusion.

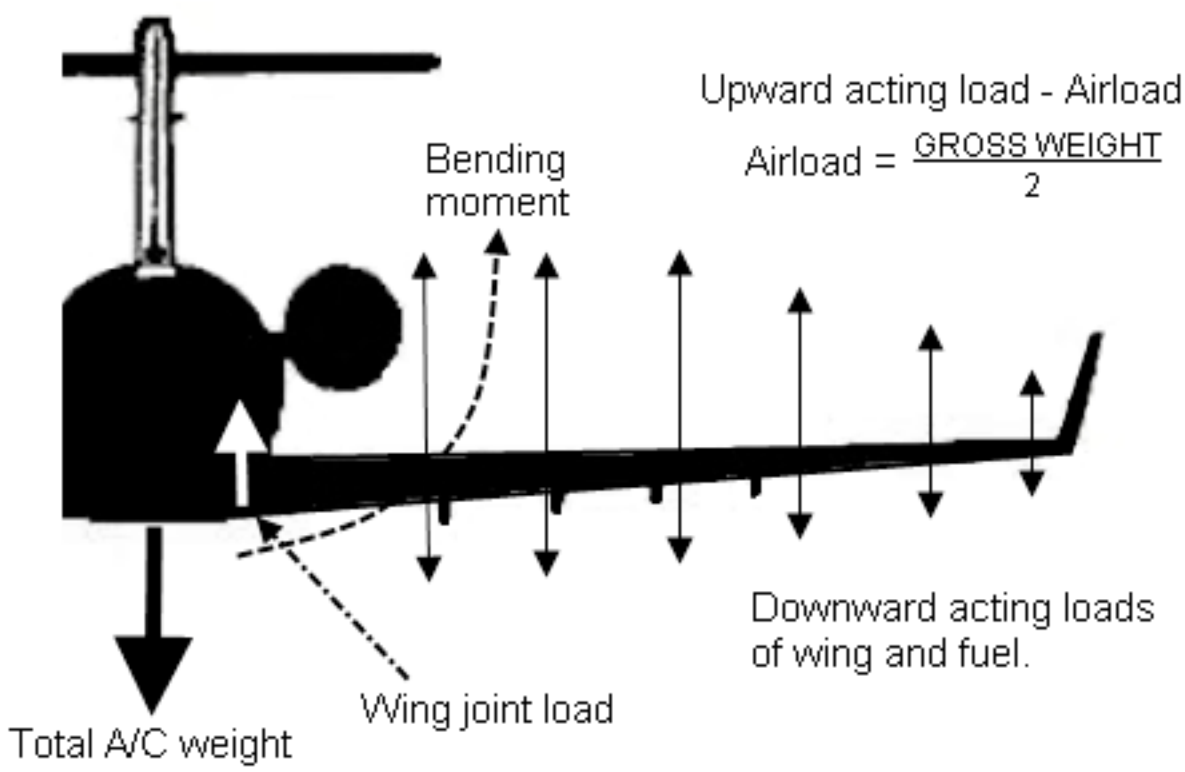
- If possible avoid severe weather conditions.

- Reduce airspeed by reducing thrust if the aircraft enters rough air, or rough air is anticipated.
- Do not reduce speed by pulling the nose up.
- Monitor the stall speed which will increase with increasing gust velocities.
- Do not extend the flaps except for approach and landing.
- If in rough air do not chase speed or altitude, and do not use manoeuvres resulting in increased load factors
- Fly attitude.

1.11.4 Gross Weight limitations.

1.11.4.1 General.

The load of the wing is affected by the air load on the wings, the wing weight including fuel, the weight of the fuselage and its content, the fuel distribution and the sequence of fuel usage.



1.11.4.2 Maximum zero (wing) fuel weight.

In level flight the total gross weight is supported by the air load on the wings where the air load acts upward acting load and the gross weight acts downward.

Since the upward acting loads on the wings are greater than those acting downwards, bending moments and upward acting loads are produced at the wing root.

The load at the wing root can be illustrated by the following example where the figures are given in tons.

Weight of fuselage and its content	14	14
Weight of wings	5	5
Fuel load	0	5
Aircraft gross weight	19	24
Lift/wing = aircraft gross weight / 2	9.5	12
Weight of the wing including fuel	-2.5	-5
Wing joint load	7	7

The above figures relates only to this sample.

From the above sample it can be seen, that the joint load remains constant as long as the fuselage and its content is kept constant. The fuel burn off-loads the wing to the same amount as it on-loads it when fuelling.

If, in the above sample, 7 tons wing joint load is the maximum permitted including safety margins, the gross weight of 19 tons is equal to the max zero fuel mass. If this weight is exceeded, the design load at the wing-tofuselage joint is exceeded.

1.11.4.3 Maximum take-off and landing weights.

Other gross weights limits to protect the aircraft structure are the maximum take-off and landing masses. These weights are structurally limited by the strength of the landing gear and the wings.

The aircraft must be designed for a rate of descent of at least 600 ft/min at maximum landing mass, and 360 ft/min at maximum take-off mass.

1.12 Contaminated Runways.

1.12.1 Effects on take-off and landing performance.

1.12.1.1 General.

About one fifth of the deceleration force is obtained from the aerodynamic drag of the aircraft, and the rest must be produced by wheel braking and reversing.

The deceleration force from the wheel brakes is equal to the friction coefficient – μ – between the tire and the runway, multiplied by the wheel load. Thus the coefficient is a measure of the braking force available and in term the braking quality of the runway.

The coefficient varies with the nature and conditions of the runway, the tire tread and wear and, especially on wet and slush covered runways, the speed of the aircraft. At high speeds aquaplaning will cause extremely low coefficient values.

1.12.1.2 Aquaplaning or hydroplaning.

Aquaplaning or hydroplaning is said to occur when the wheel loses its firm contact with the runway surface and tends to float on a layer of slush or water.

There are three such types of friction loss:

- Viscous hydroplaning, acting as a thin water film lubrication, which can occur on a very smooth runway when it is wet.
- Rubber reversion is a type of skid which may follow a prolonged skid on a wet runway. It is named for the appearance of the tire afterwards. The tire shows a patch of rubber which, due to heat, has reverted to the uncured state. The friction heat turns the water into steam hot enough to boil a spot on the tire. The soft, uncured rubber produces a seal that keeps the steam and water entrapped in the spot and makes the tire float on a cushion of steam. Once the reversion has started it may persist to very low speeds.
- Dynamic hydroplaning is like water skiing and occurs when the tire is separated from the runway surface and rides on a cushion of water.

The occurrence of dynamic hydroplaning is a function of tire pressure, aircraft speed, tire tread, runway surface and depth of fluid as follows:

- The higher the tire pressure the higher the hydroplaning speed. If all other condition for hydroplaning exists, the speed in knots is equal to P over 9 (at touchdown before the tire starts to rotate the speed is in fact P over 7.7) where P is the tire pressure in psi.
- The risk of dynamic hydroplaning is reduced with increasing depth of grooves in tires and or runways, or if the runway has a more open texture.
- Increased risk of dynamic hydroplaning is present with increasing fluid depth.

1.12.1.3 Ice.

Ice on the runway reduces braking action and controllability, and increases the landing distance considerably.

1.12.1.4 Slush.

Slush has undesirable effects on acceleration as well as on braking efficiency. Having characteristics as a fluid, it is displaced by the tires, resulting in a significant retarding force. The accompanying slush spray causes additional drag when it impacts the lower side of the aircraft, the landing gear, flaps etc.

Approximately 40% of the total slush drag is produced by the nose wheel, which also creates the major part of the spray drag.

The slush drag increases with the square of the speed up to the aquaplaning speed, and thereafter to a smaller degree because of the spray is reduced when, especially the nose gear, tends to float on the slush layer. Furthermore, the slush drag increases linearly with increasing depth of the slush.

Previously it was mentioned that just 1.5 cm of slush will increase the take-off roll with about 20%, which in term equals several tons reduction of take-off mass for a given runway.

In addition to the performance loss, the slush spray can cause several types of damage to the aircraft structure and systems. Furthermore, as it has a slippery texture, the controllability and braking can be extremely poor, particularly at high speeds caused by aquaplaning. Slush drag and spray also causes a nose down pitching moment which in turn increases the forces required to rotate the aircraft.

1.12.1.5 Standing water.

Standing water has an effect on aircraft performance similar to that of slush.

1.12.1.6 Snow.

Snow, being compactable and not creating any spray pattern, results in less performance deterioration. However, snowdrifts may create a serious hazard to operation.

1.12.2 Braking action during winter conditions.

1.12.2.1 General.

The braking action and the need for improving it must be continuously monitored by using a method to check the braking action. Caution must be exercised when the temperature is changing from mild to frost, and vice versa. When braking action is significantly different on various parts of the runway, the mean value of each third may be determined.

Consult Standing Operating Procedures if different braking action values are received, with regard to maximum permissible cross wind.

1.12.2.2 Determination by specially designed vehicles.

The testing is preferably made by special designed vehicles, giving braking action graphically, enabling quick evaluation of the situation.

The input to the instrument is obtained through the skidding of a separately slightly braked wheel.

1.12.2.3 Reports from other aircrafts.

At many airports, reports from pilots are the basis for information, regarding braking action. However, it is found that reports from landing aircrafts are at great variance even under unchanged runway conditions.

Therefore, pilot reports must be used with caution, especially not given under same actual conditions and with similar aircraft.

1.12.2.4

When conditions are such that the wheel of a test vehicle will penetrate a thin layer of slush, wet snow or water, whereas the wheels of the aircraft will not, test results will indicate a much better braking action than a landing aircraft can expect to experience. Measuring with the BV11 and SFT are regarded to give acceptable measurements, even in above mentioned case, since it is equipped with a aircraft type high pressure rubber tire, and the test run is performed at 95 km/h.