angle of bank column, which is 45°. The stall speed in miles per hour (m.p.h.) is 78 m.p.h., and the stall speed in knots would be 68 knots.

Performance charts provide valuable information to the pilot. Take advantage of these charts. A pilot can predict the performance of the airplane under most flying conditions, and this enables a better plan for every flight. The Code of Federal Regulations (CFR) requires that a pilot be familiar with all information available prior to any flight. Pilots should use the information to their advantage as it can only contribute to safety in flight.

TRANSPORT CATEGORY AIRPLANE PERFORMANCE
Transport category airplanes are certificated under Title 14 of the Code of Federal Regulations (14 CFR) part 25. The airworthiness certification standards of part 25 require proven levels of performance and guaranteed safety margins for these airplanes, regardless of the specific operating regulations under which they are employed.

MAJOR DIFFERENCES IN TRANSPORT CATEGORY VERSUS NON-TRANSPORT CATEGORY PERFORMANCE REQUIREMENTS
- Full Temperature Accountability
  All of the performance charts for the transport category airplanes require that takeoff and climb performance be computed with the full effects of temperature considered.

- Climb Performance Expressed as Percent Gradient of Climb
  The transport category airplane’s climb performance is expressed as a percent gradient of climb rather than a figure calculated in feet per minute of climb. This percent gradient of climb is a much more practical expression of performance since it is the airplane’s angle of climb that is critical in an obstacle clearance situation.

- Change in Lift-off Technique
  Lift-off technique in transport category airplanes allows the reaching of \( V_2 \) (takeoff safety speed) after the airplane is airborne. This is possible because of the excellent acceleration and reliability characteristics of the engines on these airplanes and also because of the larger surplus of power.

- Performance Requirements Applicable to all Segments of Aviation
  All airplanes certificated by the FAA in the transport category, whatever the size, must be operated in accordance with the same performance criteria. This applies to both commercial and non-commercial operations.

PERFORMANCE REQUIREMENTS
The performance requirements that the transport category airplane must meet are as follows:

TAKEOFF
- Takeoff speeds
- Takeoff runway required
- Takeoff climb required
- Obstacle clearance requirements

LANDING
- Landing speeds
- Landing runway required
- Landing climb required

TAKEOFF PLANNING
The following are the speeds that affect the transport category airplane’s takeoff performance. The flight crew must be thoroughly familiar with each of these speeds and how they are used in takeoff planning.
All of the above V speeds should be considered during every takeoff. The V1, VR, V2 and VFS speeds should be visibly posted in the cockpit for reference during the takeoff.

Takeoff speeds vary with airplane weight. Before takeoff speeds can be computed, the pilot must first determine the maximum allowable takeoff weight. The three items that can limit takeoff weight are runway requirements, takeoff climb requirements, and obstacle clearance requirements.

### RUNWAY REQUIREMENTS

The runway requirements for takeoff will be affected by the following:

- Pressure altitude
- Temperature
- Headwind component
- Runway gradient or slope
- Airplane weight

The runway required for takeoff must be based upon the possible loss of an engine at the most critical point, which is at V1 (decision speed). By regulation, the airplane’s takeoff weight has to accommodate the longest of three distances:

1. **Accelerate-Go Distance**
   - The distance required to accelerate to V1 with all engines at takeoff power, experience an engine failure at V1 and continue the takeoff on the remaining engine(s). The runway required includes the distance required to climb to 35 feet by which time V2 speed must be attained.

2. **Accelerate-Stop Distance**
   - The distance required to accelerate to V1 with all engines at takeoff power, experience an engine failure at V1, and abort the takeoff and bring the airplane to a stop using braking action only (use of thrust reversing is not considered).

3. **Takeoff Distance**
   - The distance required to complete an all-engines operative takeoff to the 35-foot height. It must be at least 15 percent less than the distance required for a one-engine inoperative engine takeoff. This distance is not normally a limiting factor as it is usually less than the one-engine inoperative takeoff distance.

These three required takeoff runway considerations are shown in figure 9-36.

### BALANCED FIELD LENGTH

In most cases, the pilot will be working with a performance chart for takeoff runway required, which will give “balanced field length” information. This means that the distance shown for the takeoff will include both the accelerate-go and accelerate-stop distances. One
Effective means of presenting the normal takeoff data is shown in the tabulated chart in figure 9-37.

The chart in figure 9-37 shows the runway distance required under normal conditions and is useful as a quick reference chart for the standard takeoff. The $V$ speeds for the various weights and conditions are also shown.

For other than normal takeoff conditions, such as with engine anti-ice, anti-skid brakes inoperative, or extremes in temperature or runway slope, the pilot should consult the appropriate takeoff performance charts in the performance section of the Airplane Flight Manual.

There are other occasions of very high weight and temperature where the runway requirement may be dictated by the maximum brake kinetic energy limits that affect the airplane’s ability to stop. Under these conditions, the accelerate-stop distance may be greater than the accelerate-go. The procedure to bring performance back to a balanced field takeoff condition is to limit the $V_1$ speed so that it does not exceed the maximum brake kinetic energy speed (sometimes called $V_{BE}$). This procedure also results in a reduction in allowable takeoff weight.
CLIMB REQUIREMENTS

After the airplane has reached the 35-foot height with one engine inoperative, there is a requirement that it be able to climb at a specified climb gradient. This is known as the takeoff flightpath requirement. The airplane’s performance must be considered based upon a one-engine inoperative climb up to 1,500 feet above the ground.

The takeoff flightpath profile with required gradients of climb for the various segments and configurations is shown in figure 9-38.

Note: Climb gradient can best be described as being a certain gain of vertical height for a given distance covered horizontally. For instance, a 2.4 percent gradient means that 24 feet of altitude would be gained for each 100 feet of horizontal distance.
1,000 feet of distance covered horizontally across the ground.

The following brief explanation of the one-engine inoperative climb profile may be helpful in understanding the chart in figure 9-38.

**FIRST SEGMENT**
This segment is included in the takeoff runway required charts and is measured from the point at which the airplane becomes airborne until it reaches the 35-foot height at the end of the runway distance required. Speed initially is \( V_{LOF} \) and must be \( V_2 \) at the 35-foot height.

**SECOND SEGMENT**
This is the most critical segment of the profile. The second segment is the climb from the 35-foot height to 400 feet above the ground. The climb is done at full takeoff power on the operating engine(s), at \( V_2 \) speed, and with the flaps in the takeoff configuration. The required climb gradient in this segment is 2.4 percent for two-engine airplanes, 2.7 percent for three-engine airplanes, and 3.0 percent for four-engine airplanes.

**THIRD OR ACCELERATION SEGMENT**
During this segment, the airplane is considered to be maintaining the 400 feet above the ground and accelerating from the \( V_2 \) speed to the \( V_{FS} \) speed before the climb profile is continued. The flaps are raised at the beginning of the acceleration segment and power is maintained at the takeoff setting as long as possible (5 minutes maximum).

**FOURTH OR FINAL SEGMENT**
This segment is from the 400 to 1,500-foot AGL altitude with power set at maximum continuous. The required climb in this segment is a gradient of 1.2 percent for two-engine airplanes, 1.5 percent for three-engine airplanes, and 1.7 percent for four-engine airplanes.

**SECOND SEGMENT CLimb LIMITATIONS**
The second segment climb requirements, from 35 to 400 feet, are the most restrictive (or hardest to meet) of the climb segments. The pilot must determine that the second segment climb is met for each takeoff. In order to achieve this performance at the higher density altitude conditions, it may be necessary to limit the takeoff weight of the airplane.
It must be realized that, regardless of the actual available length of the takeoff runway, takeoff weight must be adjusted so that the second segment climb requirements can be met. The airplane may well be capable of lifting off with one engine inoperative, but it must then be able to climb and clear obstacles. Although second segment climb may not present much of a problem at the lower altitudes, at the higher altitude airports and higher temperatures the second segment climb chart should be consulted to determine the effects on maximum takeoff weights before figuring takeoff runway distance required.

**AIR CARRIER OBSTACLE CLEARANCE REQUIREMENTS**

Regulations require that large transport category turbine powered airplanes certificated after September 30, 1958, be taken off at a weight that allows a net takeoff flightpath (one engine inoperative) that clears all obstacles either by a height of at least 35 feet vertically, or by at least 200 feet horizontally within the airport boundaries and by at least 300 feet horizontally after passing the boundaries. The takeoff flightpath is considered to begin 35 feet above the takeoff surface at the end of the takeoff distance, and extends to a point in the takeoff at which the airplane is 1,500 feet above the takeoff surface, or at which the transition from the takeoff to the enroute configuration is completed. The net takeoff flightpath is the actual takeoff flightpath reduced at each point by 0.8 percent for two-engine airplanes, 0.9 percent for three-engine airplanes, and 1.0 percent for four-engine airplanes.

Air carrier pilots therefore are responsible not only for determining that there is enough runway available for an engine inoperative takeoff (balanced field length), and the ability to meet required climb gradients; but they must also assure that the airplane will be able to safely clear any obstacles that may be in the takeoff flightpath.

The net takeoff flightpath and obstacle clearance required are shown in figure 9-39.

The usual method of computing net takeoff flightpath performance is to add up the total ground distances required for each of the climb segments and/or use obstacle clearance performance charts in the AFM. Although this obstacle clearance requirement is seldom a limitation at the normally used airports, it is quite often an important consideration under critical conditions such as high takeoff weight and/or high-density altitude. Consider that at a 2.4 percent climb gradient (2.4 feet up for every 100 feet forward) a 1,500-foot altitude gain would take a horizontal distance of 10.4 nautical miles to achieve.

**SUMMARY OF TAKEOFF REQUIREMENTS**

In order to establish the allowable takeoff weight for a transport category airplane, at any airfield, the following must be considered:

- Airfield pressure altitude
- Temperature
- Headwind component
- Runway length
- Runway gradient or slope
- Obstacles in the flightpath

Once the above details are known and applied to the appropriate performance charts, it is possible to determine the maximum allowable takeoff weight. This
weight would be the lower of the maximum weights as allowed by:

- Balanced field length required
- Engine inoperative climb ability (second segment limited)
- Obstacle clearance requirement

In practice, restrictions to takeoff weight at low altitude airports are usually due to runway length limitations; engine inoperative climb limitations are most common at the higher altitude airports. All limitations to weight must be observed. Since the combined weight of fuel and payload in the airplane may amount to nearly half the maximum takeoff weight, it is usually possible to reduce fuel weight to meet takeoff limitations. If this is done, however, flight planning must be recalculated in light of reduced fuel and range.

**LANDING PERFORMANCE**

As in the takeoff planning, certain speeds must be considered during landing. These speeds are shown below.

**LEVEL CONDITION**

<table>
<thead>
<tr>
<th>Speed</th>
<th>Definition</th>
</tr>
</thead>
<tbody>
<tr>
<td>$V_{SO}$</td>
<td>Stalling speed or the minimum steady flight speed in the landing configuration.</td>
</tr>
<tr>
<td>$V_{REF}$</td>
<td>1.3 times the stalling speed in the landing configuration. This is the required speed at the 50-foot height above the threshold end of the runway.</td>
</tr>
<tr>
<td>Approach Climb</td>
<td>The approach climb speed is the speed which would give the best climb performance in the approach configuration, with one engine inoperative, and with maximum takeoff power on the operating engine(s). The required gradient of climb in this configuration is 2.1 percent for two-engine airplanes, 2.4 percent for three-engine airplanes, and 2.7 percent for four-engine airplanes.</td>
</tr>
<tr>
<td>Landing Climb</td>
<td>This speed would give the best performance in the full landing configuration with maximum takeoff power on all engines. The gradient of climb required in this configuration is 3.2 percent.</td>
</tr>
</tbody>
</table>

**PLANNING THE LANDING**

As in the takeoff, the landing speeds shown above should be precomputed and visible to both pilots prior to the landing. The $V_{REF}$ speed, or threshold speed, is used as a reference speed throughout the traffic pattern or instrument approach as in the following example:

- $V_{REF}$ plus 30K ......Downwind or procedure turn
- $V_{REF}$ plus 20K ......Base leg or final course inbound to final fix
- $V_{REF}$ plus 10K ......Final or final course inbound from fix (ILS final)
- $V_{REF}$ ..................Speed at the 50-foot height above the threshold

**LANDING REQUIREMENTS**

The maximum landing weight of an airplane can be restricted by either the approach climb requirements or by the landing runway available.

**APPROACH CLIMB REQUIREMENTS**

The approach climb is usually more limiting (or more difficult to meet) than the landing climb, primarily because it is based upon the ability to execute a missed approach with one engine inoperative. The required climb gradient can be affected by pressure altitude and temperature and, as in the second segment climb in the takeoff, airplane weight must be limited as needed in order to comply with this climb requirement.

**LANDING RUNWAY REQUIRED**

The runway distance needed for landing can be affected by the following:

- Pressure altitude
- Temperature
- Headwind component
- Runway gradient or slope
- Airplane weight

In computing the landing distance required, some manufacturers do not include all of the above items in their charts, since the regulations state that only pressure altitude, wind, and airplane weight must be considered. Charts are provided for anti-skid on and anti-skid off conditions, but the use of reverse thrust is not used in computing required landing distances.

The landing distance, as required by the regulations, is that distance needed to land and come to a complete stop from a point 50 feet above the threshold end of the runway. It includes the air distance required to travel from the 50-foot height to touchdown (which can consume 1,000 feet of runway distance), plus the stopping
distance, with no margin left over. This is all that is required for 14 CFR part 91 operators (non-air carrier), and all that is shown on some landing distance required charts.

For air carriers and other commercial operators subjected to 14 CFR part 121, a different set of rules applies which states that the required landing distance from the 50-foot height cannot exceed 60 percent of the actual runway length available. In all cases, the minimum airspeed allowed at the 50-foot height must be no less than 1.3 times the airplane’s stalling speed in the landing configuration. This speed is commonly called the airplane’s VREF speed and will vary with landing weight. Figure 9-40 is a diagram of these landing runway requirements.

**SUMMARY OF LANDING REQUIREMENTS**

In order to establish the allowable landing weight for a transport category airplane, the following details must be considered:

- Airfield pressure altitude
- Temperature
- Headwind component
- Runway length
- Runway gradient or slope
- Runway surface condition

With these details, it is possible to establish the maximum allowable landing weight, which will be the lower of the weights as dictated by:

- Landing runway requirements
- Approach climb requirements

In practice, the approach climb limitations (ability to climb in approach configuration with one engine inoperative) are seldom encountered because the landing weights upon arrival at the destination airport are usually light. However, as in the second segment climb requirement for takeoff, this approach climb gradient must be met and landing weights must be restricted if necessary. The most likely conditions that would make the approach climb critical would be the landings at high weights and high-pressure altitudes and temperatures, which might be encountered if a landing were required shortly after takeoff.

Landing field requirements can more frequently limit an airplane’s allowable landing weight than the approach climb limitations. Again, however, unless the runway is particularly short, this is seldom problematic as the average landing weight at the destination seldom approaches the maximum design landing weight due to fuel burn off.

![Figure 9-40. Landing runway requirements.](image-url)
EXAMPLES OF PERFORMANCE CHARTS

Figures 9-41 through 9-62 are examples of charts used for transport category airplanes.
Figure 9-41. Minimum takeoff power at 1700 r.p.m.

Figure 9-42. Takeoff distance—Flaps takeoff.
ACCELERATE-STOP — FLAPS TAKEOFF

ASSOCIATED CONDITIONS:

POWER .......................... TAKE-OFF POWER SET
BEFORE BRAKE RELEASE
2. BOTH ENGINES IDLE AT V1 SPEED
AUTOFEATHER .................. ARMED
BRACING ......................... MAXIMUM
RUNWAY ......................... PAVED, LEVEL, DRY SURFACE

NOTE: FOR OPERATION WITH ICE VANES EXTENDED,
ADD 9 °C TO THE ACTUAL OAT BEFORE
ENTERING GRAPH.

WEIGHT - POUNDS  | V1 - KNOTS
---|---
18,000  | 108
16,000  | 107
14,000  | 102
12,000  | 102
10,000  | 102

Figure 9-43. Accelerate stop—Flaps takeoff.
Figure 9-44. Climb – Two engines—Flaps up.
Figure 9-45. Time, fuel, and distance to cruise climb.
Figure 9-46. Climb—One engine inoperative.
Figure 9-47. Service ceiling—One engine inoperative.