CHAPTER 8

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CHAPTER 8

DESCENT PERFORMANCE

8.1 INTRODUCTION

This chapter examines the theory and flight tests to determine aircraft descent performance. By definition, whenever an aircraft is in an unstalled descent, it is in either a glide or a dive. For purposes of this manual, a glide is defined as unaccelerated flight at a descent angle less than or equal to fifteen degrees, while a dive is defined as flight with a descent angle greater than fifteen degrees. Glides or dives may be either power-on or power-off maneuvers in different configurations, so a wide range of gliding and diving performance is possible with any given airplane.

Flight testing of an airplane’s descent performance generally involves only the power-off case where the term power-off is used to define the idle thrust/minimum torque/minimum power glide performance.

While obtaining descent data in low drag configurations with power-off can be considered a rather benign flight test, the character of the testing changes dramatically for tests required to define the flameout landing pattern. And even the benign descent tests become exciting if an engine or other critical system fails.

8.2 PURPOSE OF TEST

The purpose of this test is to investigate aircraft descent performance characteristics to determine time, fuel used, and distance traveled. The tests are performed at different airspeeds and in different configurations to obtain data for the NATOPS manual including:

1. Optimum descent airspeed or Mach number/airspeed schedules.
2. Penetration descent schedules.
3. Precautionary approach patterns.
4. Flameout approach patterns.

8.3 THEORY

For stabilized, level flight, engine thrust or power is adjusted to balance the aircraft's drag. If the thrust or power is reduced to zero, the power required to maintain the aircraft's speed comes from the aircraft's time rate of change of kinetic and potential energy. The rate of energy expenditure varies directly with the rate of descent and linear acceleration.

For the discussion of gliding or power-off flight, the thrust or power is assumed to be negligible, and gliding performance is measured in terms of:

1. Minimum rate of descent (endurance).
2. Minimum glide angle (range).

With an aircraft in a steady power-off glide, the forces on the aircraft are lift, drag and weight as indicated in figure 8.1.

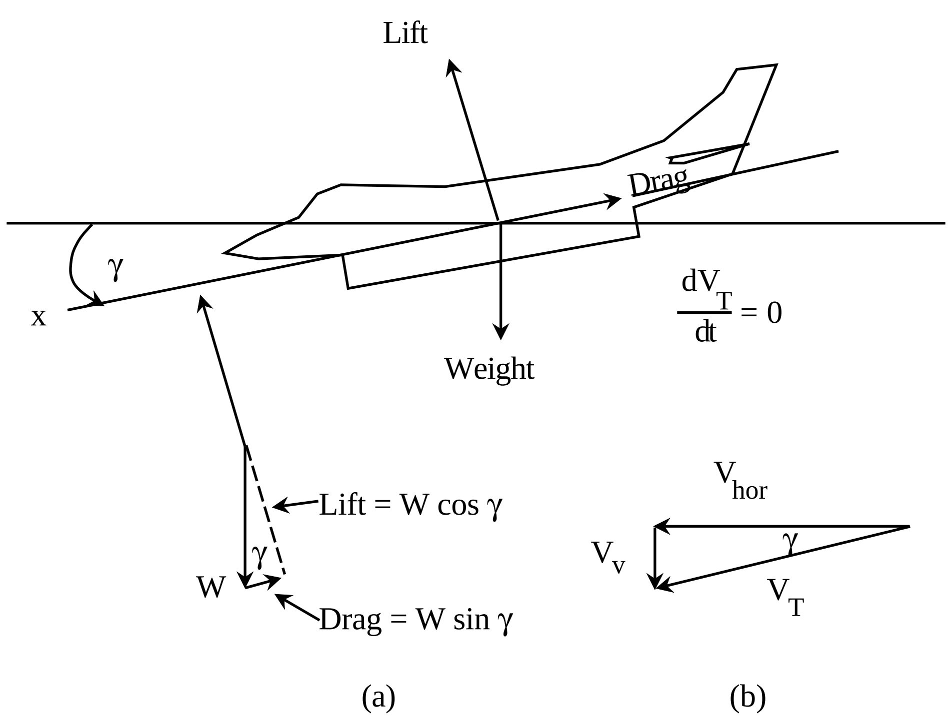


Figure 8.1
FORCES IN A STEADY GLIDE

The angle between the flight path and the horizon is called the flight path angle (γ); for a glide the flight path angle is negative. The descent (glide) angle is a function of both the descent rate (dh/dt) and true airspeed (V_T).

To evaluate descent performance, the true airspeed is assumed to be constant ($dV_T/dt = 0$).

In addition to glide angle, descent performance is described in terms of glide ratio (GR) defined as the ratio of horizontal to vertical velocity.

Since the condition is steady flight ($dV_T/dt = 0$), figure 8.1 (a) shows the forces are in equilibrium and resolving the forces perpendicular and parallel to the flight path gives:

$$\sum F_z = L = W \cos \gamma \qquad \text{(Eq 8.1)}$$

$$\sum F_x = D = W \sin \gamma \qquad \text{(Eq 8.2)}$$

$$\frac{L}{D} = \frac{\cos \gamma}{\sin \gamma} = \cot \gamma \qquad \text{(Eq 8.3)}$$

The glide angle (γ) is a minimum when the ratio of lift to drag is a maximum.

Evaluating the vector diagram, figure 8.1 (b), where V_T = flight path speed produces:

$$V_{hor} = V_T \cos \gamma \qquad \text{(Eq 8.4)}$$

$$V_v = V_T \sin \gamma \qquad \text{(Eq 8.5)}$$

$$\frac{V_{hor}}{V_v} = \frac{V_T \cos \gamma}{V_T \sin \gamma} = \cot \gamma = \frac{L}{D} \qquad \text{(Eq 8.6)}$$

$$\sin \gamma = \frac{V_v}{V_T} \qquad \text{(Eq 8.7)}$$

$$\gamma = \sin^{-1}\left(\frac{V_v}{V_T}\right) \qquad \text{(Eq 8.8)}$$

$$\gamma = \sin^{-1}\left(\frac{dh/dt}{V_T}\right) \qquad \text{(Eq 8.9)}$$

$$\frac{L}{D} = \cot\left[\sin^{-1}\left(\frac{dh/dt}{V_T}\right)\right] \qquad \text{(Eq 8.10)}$$

Generally measuring horizontal velocity directly is not convenient, so substituting $V_{hor} = V_T \cos\gamma$ into Eq 8.6, provides a more usable equation:

$$\text{Glide Ratio} = \frac{L}{D} = \frac{V_T \cos\gamma}{V_v} \qquad \text{(Eq 8.11)}$$

When the glide ratio is greater than 7 to 1, cos γ is between 0.99 and 1.0. Since the glide ratio of most tactical aircraft fit this criteria in the low drag, clean configuration, the equation simplifies to:

$$GR = \frac{L}{D} \approx \frac{V_T}{V_v} \qquad \text{(Eq 8.12)}$$

For small descent angles the horizontal speed (V_{hor}) is almost the same as the flight path speed (V_T). As the descent angle increases, this approximate identity is no longer valid.

Resolving the vertical and horizontal velocity components from figure 8.1 (b), and plotting V_{hor} against V_v yields a hodograph (Figure 8.2).

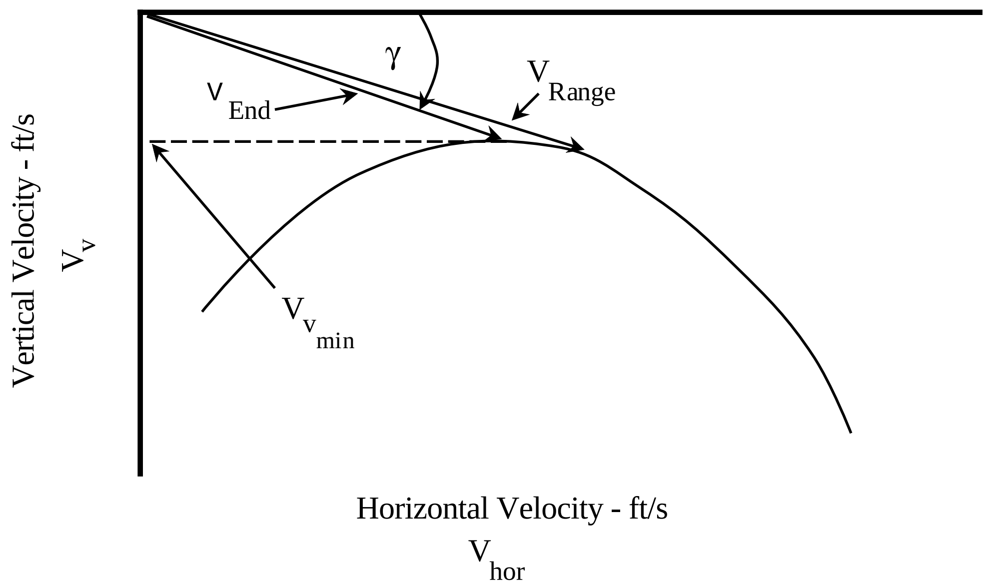


Figure 8.2
HODOGRAPH

On a hodograph, the radius vector from the origin to any part on the plot has a length proportional to the flight path speed and makes an angle to the horizontal equal to the actual descent angle (γ).

1. The vertical axis is: $dh/dt = V_v$ = rate of descent (ROD) = $V_T \sin\gamma$.
2. The horizontal axis is $V_{hor} = V_T \cos\gamma$.

Thus by the Pythagorean theorem, a line drawn from the origin to some point on the hodograph has a vector length:

$$V_T = \sqrt{V_T^2 \sin^2\gamma + V_T^2 \cos^2\gamma} = \sqrt{V_T^2 \left(\sin^2\gamma + \cos^2\gamma\right)} \qquad \text{(Eq 8.13)}$$

Where:

D	Drag	lb
F_z	Force perpendicular to flight path	lb
F_x	Forces parallel to flight path	lb
γ	Flight path angle	deg
GR	Glide ratio	
h	Tapeline altitude	ft
L	Lift	lb
t	Time	s
V_{hor}	Horizontal velocity	kn or ft/s
V_T	True airspeed	kn or ft/s
V_v	Vertical velocity	ft/s
W	Weight	lb.

The angle made by the resultant velocity vector with the horizontal is γ. Therefore the hodograph representation gives the:

1. Rate of descent.
2. Horizontal speed.
3. Flight path speed.
4. Flight path angle.

8.3.1 WEIGHT EFFECT

As shown in Eq 8.3, for a given aircraft, the glide angle is determined solely by its lift-to-drag ratio, which is independent of weight. Note the higher the lift-to-drag ratio, the shallower the descent angle (assuming no wind). The hodograph in figure 8.3 shows an aircraft at two different weights.

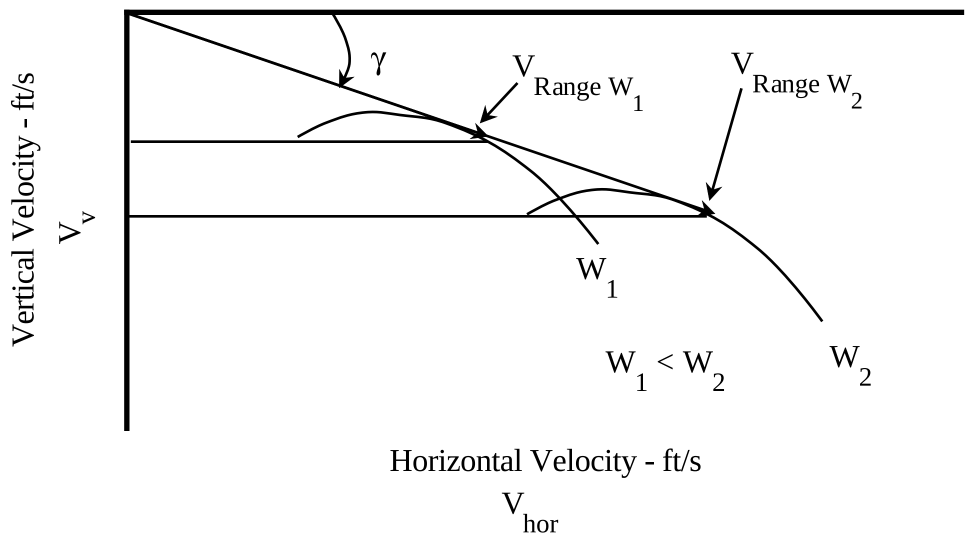


Figure 8.3
WEIGHT EFFECT ON DESCENT PERFORMANCE

To fly at the same $\left.\frac{L}{D}\right|_{max}$ (same descent angle) at a higher gross weight, the flight path airspeed increases and the rate of descent increases. At the higher airspeed for the higher gross weight, the increase in drag is offset by the increased weight component along the flight path.

8.3.2 WIND EFFECT

The effects of head wind or a tail wind can be resolved by displacing the origin of the hodograph by the amount of the head wind or tail wind component (Figure 8.4).

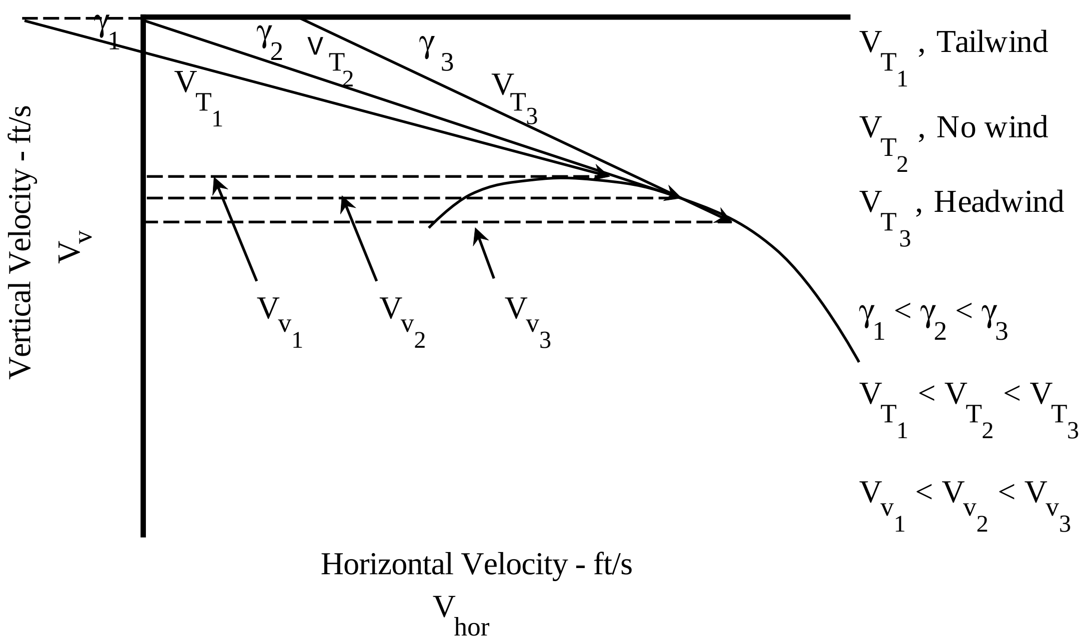


Figure 8.4

TAIL WIND / HEAD WIND EFFECT ON DESCENT PERFORMANCE

For maximum range in a tail wind, you must fly slower than when flying for range in the no wind case. The aircraft remains airborne for a longer time, taking advantage of the tail wind.

When gliding for maximum range in a tail wind jettisoning weight helps. This has the effect of increasing the endurance and allows the aircraft to gain more advantage from the tail wind.

In a head wind, the speed for optimum range is greater than the minimum drag speed and the time for which the aircraft is subject to the adverse wind effect is reduced.

When gliding for maximum range in a head wind, retaining weight helps because the wind affects the aircraft for a shorter time. To summarize:

1. No wind - weight has no effect on range.
2. Tail wind - jettison weight for best range.
3. Head wind - retain weight for best range.

8.3.3 DRAG EFFECT

As shown in figure 8.5, the effect of increasing drag is to move the hodograph plot to the left and down where the maximum glide speed occurs at a slower airspeed and at a higher rate of descent.

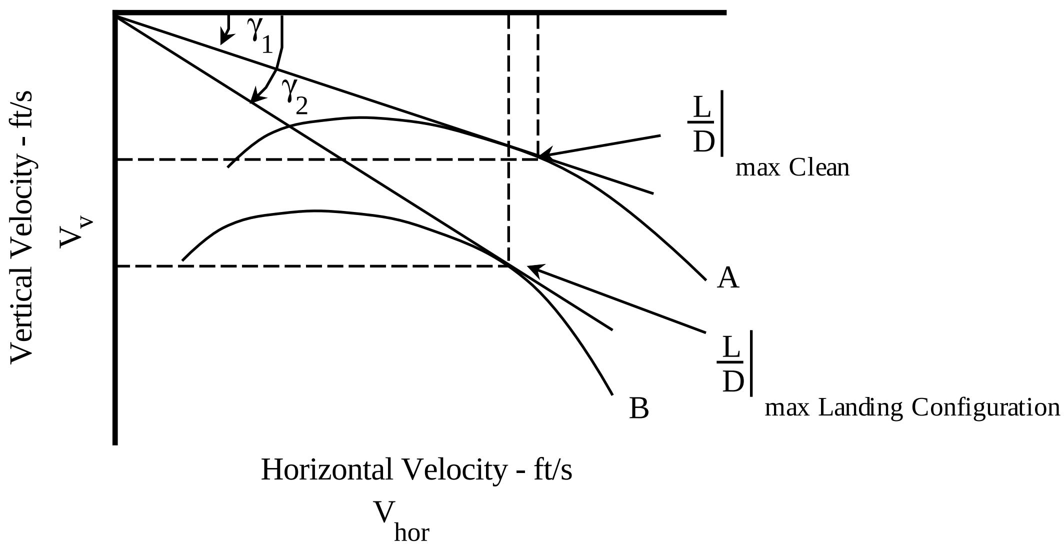


Figure 8.5
INCREASED DRAG EFFECT ON DESCENT PERFORMANCE

Understanding this relationship is most important when specifying a precautionary / flameout landing pattern. In preparing for landing when high drag items like gear, flaps, and speed brakes are extended, the descent performance of the aircraft jumps from figure 8.5 curve A to curve B. During the transition from the stabilized glide condition in curve B, to establish a flight path tangential to the runway during the landing flare, kinetic energy is traded for potential energy. However, once the deceleration is stopped, the rate of descent is fixed. As might occur with a flare which is too high above the runway, the aircraft would be at a point where a further decrease in airspeed is not possible due to stall, so the landing which results might be at an excessive rate of descent.

8.3.4 AIRSPEED EFFECT

Throughout the previous discussion, the aircraft was assumed to be descending at a constant true airspeed. Since many descents are done at a decelerating V_T (constant V_o) the effect of $dV_T/dt \neq 0$ is evaluated.

For an aircraft which is not accelerating, as in Eq 8.10, the L/D ratio for an aircraft in the power-off case could be calculated from measured flight parameters:

$$\frac{L}{D} = \cot\left[\sin^{-1}\left(\frac{dh/dt}{V_T}\right)\right] \qquad \text{(Eq 8.10)}$$

In most cases a descent is flown with dV_T/dt decreasing. For the case where V_c = constant, the true airspeed is decreasing as the aircraft descends. Modifying Eq 8.1 and Eq 8.2 to account for the deceleration and summing the forces along the flight path:

$$\sum F_x = W \sin\gamma - D = \frac{W}{g}\frac{dV_T}{dt} \qquad \text{(Eq 8.14)}$$

Re-arranging as:

$$\frac{D}{W} = \sin\gamma - \frac{1}{g}\frac{dV_T}{dt} \qquad \text{(Eq 8.15)}$$

The flight path acceleration dV_T/dt can be expressed as:

$$\frac{dV_T}{dt} = \frac{dV_T}{dh}\frac{dh}{dt} \qquad \text{(Eq 8.16)}$$

Substituting in Eq 8.15 gives:

$$\frac{D}{W} = \sin\gamma - \frac{1}{g}\frac{dV_T}{dh}\frac{dh}{dt} \qquad \text{(Eq 8.17)}$$

Since:

$$\frac{dh}{dt} = V_T \sin\gamma \qquad \text{(Eq 8.18)}$$

Further substitution in Eq 8.17 gives:

$$\frac{D}{W} = \sin\gamma - \frac{1}{g}\frac{dV_T}{dh} V_T \sin\gamma \qquad \text{(Eq 8.19)}$$

The sum of the forces perpendicular to the flight path figure 8.1 (a) (regardless of flight path acceleration) can be resolved as:

$$\sum F_z = L = W \cos\gamma \qquad \text{(Eq 8.1)}$$

Or:

$$\frac{L}{W} = \cos\gamma \qquad \text{(Eq 8.20)}$$

Combining Eq 8.19 and Eq 8.20 produces:

$$\frac{L}{D} = \cot\gamma \left[\frac{1}{1 - \frac{V_T}{g}\frac{dV_T}{dh}} \right] \qquad \text{(Eq 8.21)}$$

Expressed in terms of flight parameters which can be measured:

$$\frac{L}{D} = \cot \left[\sin^{-1}\left(\frac{(dh/dt)}{V_T} \right) \right] \left[\frac{1}{1 - \frac{V_T}{g}\frac{dV_T}{dh}} \right] \qquad \text{(Eq 8.22)}$$

Eq 8.22 is Eq 8.10 modified by the flight path acceleration.

The instantaneous glide ratio, regardless of acceleration or deceleration ($dV_T/dh \neq 0$) is still the ratio of V_v/V_{hor} forming the descent angle γ where the glide ratio is cot γ:

$$\frac{L}{D} = \left[\frac{GR}{1 - \frac{V_T}{g} \frac{dV_T}{dh}} \right] \qquad \text{(Eq 8.23)}$$

$$GR = \frac{L}{D} \left[1 - \frac{V_T}{g} \frac{dV_T}{dh} \right] \qquad \text{(Eq 8.24)}$$

Where:

D	Drag	lb
F_z	Force perpendicular to flight path	lb
F_x	Force parallel to flight path	lb
γ	Flight path angle	deg
g	Gravitational acceleration	ft/s^2
GR	Glide ratio	
h	Tapeline altitude	ft
L	Lift	lb
t	Time	s
V_T	True airspeed	ft/s
W	Weight	lb.

The lift-to-drag ratio is a function of the drag polar and is independent of the descent path. The actual glide ratio is the lift-to-drag ratio modified by the path. In the example above where the aircraft is decelerating, the quantity $(1- \frac{V_T}{g} \frac{dV_T}{dh})$ is greater than 1, which results in the actual glide path angle being less than the aircraft L/D.

8.4 TEST METHODS AND TECHNIQUES

8.4.1 SAWTOOTH DESCENT

The sawtooth descent consists of a series of short descents at a constant observed airspeed (V_o) covering the range of desired test airspeeds. The altitude band for the descent is usually 1,000 ft either side of the target altitude for high L/D configurations or as much as 3,000 ft either side of the target altitude for low L/D configurations. Subsequent flights evaluate different target altitudes with the same test airspeeds.

Establish configuration and thrust/power setting above the desired start altitude. Allow sufficient altitude for the engine(s) to stabilize at the test thrust/power setting and stabilize at the desired airspeed before entering the data band.

Although the tolerance on V_o is ± 1 kn, this must not be achieved at the expense of a loss of smoothness. If a small airspeed error is made while establishing the descent, maintaining the off-target speed as accurately as possible is preferred rather than trying to correct to the target airspeed and risk aborting the entire run. While a photopanel or other automatic recording device can be used, good results may be obtained with a minimum number of hand-held data points using a stop watch.

To minimize wind shear, determine the wind direction and magnitude so all descent testing can be made perpendicular to the average wind in the altitude band being flown.

A typical flight data card is shown in figure 8.6.

Target V_o	V_o	Initial H_P	Final H_P	Δt	Fuel	OAT	Misc

Figure 8.6
SAWTOOTH DATA CARD

The exact time of entering and leaving the altitude band is recorded by a stopwatch or an instrumentation system.

Once through the altitude increment, record data, and a initiate climb above the altitude band for another run. As many points as possible are flown at each altitude.

Record actual in-flight V_o, W, time, fuel counts or fuel remaining, and either outside air temperature or time of day so temperature can be obtained by other meteorological methods. The card can be expanded to record other parameters such as angle of attack, engine RPM, torque, etc. On the back of the data card, keep a running plot of observed time to descend versus V_o and before leaving the test altitude, examine the plot for points which need repeating.

8.4.1.1 DATA REQUIRED

1. Time: Record elapsed time from the beginning of the altitude band to the end, or two minutes, whichever comes first.
2. Altitude: Record the observed pressure altitude (H_{P_o}) band for each point.
3. Velocity: Record observed airspeed, V_o.
4. OAT or T_a: Record ambient air temperature from on-board instrumentation at target altitude. (May be obtained from direct observation).
5. Fuel weight: Record the fuel remaining to determine aircraft gross weight.
6. Miscellaneous: Record other information desired such as RPM, angle of attack, and torque for a turboprop.

Additional data and information associated with the engine management criteria are important for the descent evaluation. For example:

1. Jet exhaust nozzle position at idle thrust and the minimum thrust setting to keep the nozzle closed.
2. Heating/air conditioning, pressurization, and anti-ice systems operation at low poser.
3. Engine and other aircraft systems operation limits at low power settings.

8.4.1.2 TEST CRITERIA

Allow sufficient altitude for the engine(s) to stabilize and the airplane to stabilize at the desired airspeed before entering the data band. Smoothness is just as important as in acceleration runs and for the same reasons. If a small airspeed error is made while establishing the test conditions, it is better to maintain the incorrect speed as accurately as possible, rather than try to correct it and risk aborting the entire run.

1. Balanced (ball centered) wings level, unaccelerated flight.
2. Engine bleed air system OFF, or operated in a normal flight mode.
3. Stabilized engine thrust/power setting.
4. Stabilize before the altitude band.
5. Altimeter: 29.92, standby.
6. Conduct test 90˚ to wind direction.
7. Bank angle ≤ 10˚.
8. Heading change ≤ 30˚.
9. Normal acceleration ± 0.1 g.

8.4.1.3 DATA REQUIREMENTS

1. Test altitude band ± 1000 ft about a target altitude.
2. V_o ± 1 kn with smooth corrections.

8.4.1.4 SAFETY CONSIDERATIONS

As with any descent, the field of view from most aircraft makes it difficult to clear the area in front and below the test track. This aircraft characteristic combined with the head down requirement to fly accurate data points may impact lookout doctrine. In multi-place aircraft, distinct responsibility should be assigned for maintaining an active lookout.

With prolonged operation at low thrust/power settings, the operation of the engine and other related systems should be evaluated before setting the minimum safety altitude where the descent testing will be terminated. For most aircraft this can be between 3,000 and 5,000 ft AGL.

8.4.2 CHECK DESCENT TEST

The check descent test is flown to compare the standard day descent performance of an aircraft in a specific configuration to results predicted from sawtooth descents. The three main areas of investigation are:

1. Time to descent.
2. Distance traveled.
3. Fuel used.

In addition, data may be obtained on various engine parameters such as engine speed, exhaust gas temperature, engine pressure ratio, gross thrust, angle of attack, etc. These are useful to the analyst but are secondary to the three main parameters. The general method is to descend the aircraft from just below the maximum ceiling to a minimum safety altitude while maintaining precisely a predetermined descent schedule. This schedule may be a minimum rate of descent, maximum range schedule, a schedule recommended by the manufacturer, or some other descent schedule of interest. Take care to specify the schedule flown on each descent performance chart.

Record data at approximately equal increments of altitude and include time, speed, fuel flow, temperature, and any other desired parameters. For most jet aircraft, a mechanical recording means is necessary to obtain simultaneous reading of the many parameters of interest.

After the schedule to be flown is determined, data cards are prepared to record the descent data as in figure 8.7.

	t	Fuel temp	Fuel density	OAT or T_a	Fuel remaining	
Prior to Start	NA					
Start		NA	NA			
Taxi		NA	NA			
Takeoff		NA	NA			
t	H_{P_o}	V_o target	V_o actual	OAT or T_a	Fuel remaining	Misc

Figure 8.7

CHECK DESCENT

Adjust target points for instrument error and position error for both the airspeed indicator and altimeter. If the anticipated rate of descent is low, data are recorded every 1000 to 2000 ft. If the rate of descent is high, every 5000 ft is sufficient.

An area of smooth air, light winds, and stable temperature gradients from ground level to the aircraft's maximum ceiling is desirable. The test area can be sampled via a survey balloon or another aircraft for wind and temperature data. Plan the flight to descend perpendicular to the wind direction.

Since gross weight, fuel weight, and fuel density are important, fuel and weigh the aircraft prior to commencement of tests. Fuel samples are taken and tested for temperature and density. Record fuel remaining and time for start, taxi, takeoff, and climb to descent schedule whenever conditions permit.

During the descent, trim the aircraft. Maintain the descent schedule to within 5 kn, if possible. A rapid cross-check between external horizon and the airspeed indicator is required. If the pitch attitude is very steep, it may be necessary to substitute the aircraft attitude indicator for the external horizon during initial portions of the descent.

Wind gradients appear as sudden airspeed changes. If these affect the descent speed schedule, a small but immediate attitude correction is necessary. If the wind gradient effect subsides, apply a counter correction to prevent a speed error in the opposite direction.

At high altitudes, the problem of maintaining a precise speed schedule is difficult. A slight rate of change of indicated airspeed involves a large rate of change of kinetic energy. Any undesirable trend is difficult to stop especially with relatively less effective aerodynamic controls. The best way to cope is to avoid errors by a rapid cross-check, precise control, and constant attention to trim. If corrections are necessary, avoid over controlling due to hysteresis in the airspeed indicator.

If the descent must be interrupted, stop the descent at a given pressure altitude, noting V_o, fuel, time, and distance if available. Climb above the altitude at which the descent was stopped. Maneuver as required and re-intercept the descent schedule as soon as possible to minimize gross weight change. Intercept the descent using a 1,000 ft overlap from the break off pressure altitude at the airspeed recorded when the interrupt occurred.

The test for a turboprop aircraft is identical to the jet test. In this case however, engine torque and engine shaft horsepower (ESHP) are adjusted in the descent.

8.4.2.1 DATA REQUIRED

Record the following data at each increment, which should be as often as possible, but no greater than each 5000 ft or 2 minutes, for hand held data:

1. Time (t).
2. Observed airspeed (V_o).
3. Observed pressure altitude (H_{P_o}).
4. Temperature (OAT or T_a).
5. Fuel remaining (W_f), or start and end fuel weight.
6. Distance (d).

8.4.2.2 TEST CRITERIA

1. Balanced (ball centered) wings level, unaccelerated flight.
2. Engine bleed air system OFF, or operated in a normal flight mode.
3. Stabilized engine thrust/power setting.
4. Stabilize before the altitude band.
5. Altimeter: 29.92, standby.
6. Conduct test 90˚ to wind direction.
7. Bank angle ≤ 10˚.
8. Heading change ≤ 30˚.
9. Normal acceleration ± 0.1 g.

8.4.2.3 DATA REQUIREMENTS

1. Airspeed ± 5 kn or 0.01 M.

8.4.2.4 SAFETY CONSIDERATIONS

As with the sawtooth descent, the check descent uses prolonged operation at low thrust/power settings. Therefore, the operation of the engine and other related systems has to be evaluated before setting the minimum safety altitude where the descent testing will be terminated. For most aircraft this can be between 3,000 and 5,000 ft AGL.

8.4.3 PRECAUTIONARY / FLAMEOUT APPROACH

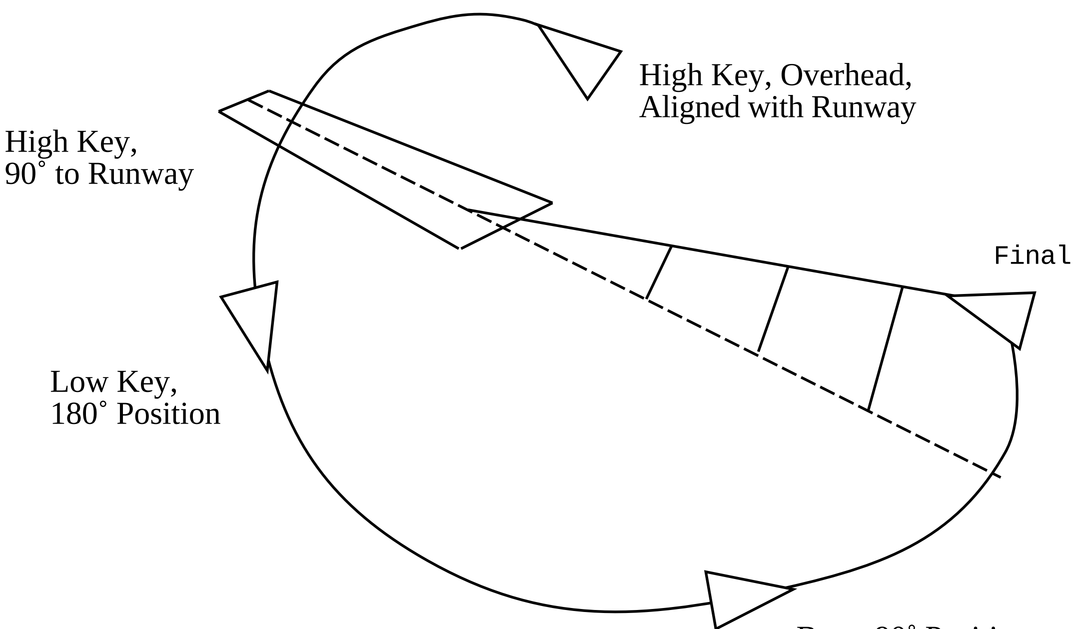
A precautionary approach is a special approach profile flown when a malfunction makes the operation of critical aircraft systems questionable. Some of the circumstances when a precautionary approach might be appropriate are:

1. Low engine oil pressure.
2. Engine stall.
3. Engine instability (temperature/vibration).
4. Critically low fuel.
5. Engine fire indication.
6. Suspected FOD.
7. Main hydraulic pressure loss.
8. Flight control malfunction.

Generally, the precautionary approach profile is designed to keep the pilot within the ejection seat envelope as long as possible. Typically the last few seconds of the profile are out of the envelope, unless the pilot performs a pull up maneuver.

There are also situations during engine out testing or evaluation of new engine components when the re-light envelope is verified by flight test. Flameout landing pattern check points need to be identified. Also, in extreme conditions when impossible or impracticable to abandon the aircraft, a flameout approach may be the only alternative.

With the advent of high fidelity simulators, various precautionary/flameout patterns can be evaluated before the actual flight test work is done. The ultimate objective of a precautionary / flameout approach is to make a safe landing reasonably close to the desired touchdown point. Achieving this result is an iterative combination of a number of factors defined in figures 8.8 and 8.9. Working from the touchdown point backwards to define the approach parameters, the first step is to determine the desired touchdown speed. This speed is generally dictated by the margin of aircraft control in all axes. The touchdown speed is also a function of aircraft geometry. An aircraft may be controllable below an airspeed at which the empennage or tailpipe may contact the runway (F-16). Another constraint on touchdown speed is tire limit speed. Also, if reducing main gear loads on touchdown is a factor, a relatively high touchdown speed may be required to increase the control over the rate of descent at touchdown. Therefore, all these factors: controllability, aircraft geometry, tire speed, and rate of descent may determine the target touchdown speed.

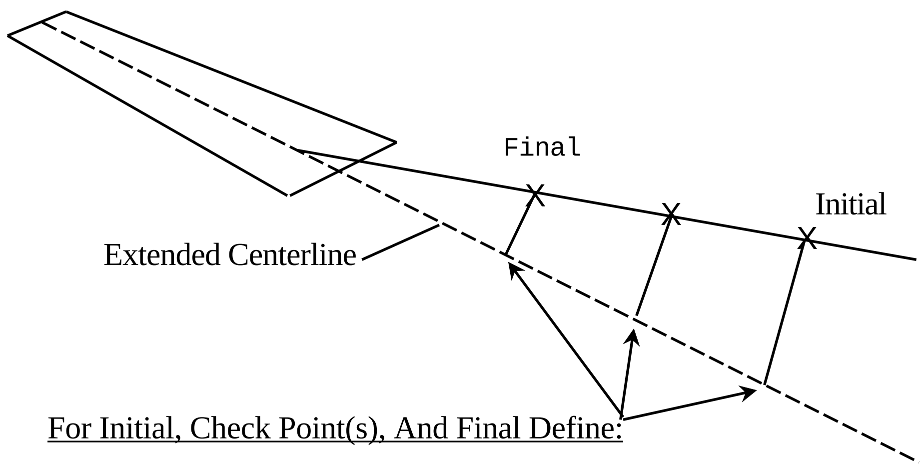


<u>For High Key, Low Key, Base, And Final Define</u>:

- Configuration
- Position with Respect to Runway
- Altitude
- Airspeed
- Wind Correction
- Weight Correction

Figure 8.8

OVERHEAD PRECAUTIONARY/FLAMEOUT PATTERN



For Initial, Check Point(s), And Final Define:

- Configuration
- Distance From Runway
- Altitude
- Airspeed
- Wind Correction
- Weight Correction

Figure 8.9

STRAIGHT-IN PRECAUTIONARY/FLAMEOUT PATTERN

After determining the touchdown speed, determine the final approach speed. The minimum final approach speed may be dictated by the ability to flare, or by the ability to accurately fly to the pre-flare aim point and touchdown near the desired touchdown point. Approaches with the gear and flaps down can result in steep flight path angles and high rates of descent. Choose an airspeed which arrests the high rate of descent with some safety margin. The maximum final approach speed is often dictated by some aircraft structural or operating characteristic limit. Final approach speed may be limited by maximum gear down operating speed.

Another problem occurs when the aircraft is flown very close to its maximum L/D capability (assume L/D > 4). In this case, touchdown accuracy deteriorates because it becomes more difficult to account for winds and errors made earlier in the pattern prior to reaching final. For a given length final approach, the shorter time on final yields the better touchdown accuracy.

The distance and time from flare to touchdown can also define a maximum final approach airspeed because an extremely long time can adversely affect touchdown accuracy. The typical target final approach airspeed is roughly midway between the minimum and maximum airspeeds and allows about a 10% variance either way. This 10% adjustment factor allows for airspeed changes caused by gusts or wind shears and makes it possible to make fine adjustments to the glide slope in order to maintain a constant pre-flare aim point.

In summary, the final approach airspeed is largely dependent on the aircraft handling and performance characteristics during the flare, which is the time from the start of rotation to touchdown attitude. Final approach is flown at a constant, low angle of attack, which means airspeed is high relative to touchdown speed. At flare initiation, the angle of attack is increased and held approximately constant. The increased load factor reduces the rate of descent. The rate of descent is arrested typically by 100 to 200 ft AGL where another constant glide path is established to touchdown.

The flare attitude is established by determining the altitude required to arrest the rate of descent using a comfortable pitch rate and increase in load factor (moderate increase in angle of attack). Cross check altitude to start the flare then rotate the aircraft at a rate which arrests the descent at the desired altitude above the ground.

The final glide path is shallow, about 3 degrees, with the angle of attack and pitch attitude slowly increasing as the airspeed bleeds off to touchdown. Unless the aircraft has been configured prior to or at pattern entry, the final landing configuration is established at this time. If the landing gear are to be extended during the final glide, gear extension time and pitching moment changes are important considerations (Space Shuttle).

Other considerations during the final flare and touchdown are the deceleration rate, the ability to adjust the final sink rate, the changes in stability as the angle of attack increases, and the field of view (back seat of a trainer). All of these items contribute to the ease or difficulty in controlling the final touchdown. If the deceleration rate is too high, the adjustment of the touchdown rate of descent is possible only once. After this one attempt, any rotation to a higher angle of attack only increases the sink rate because of the large airspeed loss during the first rotation. This requires the aircraft be landed perfectly on the first rotation after entering the 3-degree glide slope. At the other extreme, if the deceleration rate is too low, a long flare covering excessive distance results.

Entry to final sets the minimum low key altitude and airspeed. From this minimum, a comfortable normal altitude and airspeed for the low key is established. Another consideration which can dictate a minimum time for the glide or pattern is battery life or other aircraft emergency system limitations.

The important concept in flying the pattern or gliding to the pattern is to understand the options for L/D control. These options are: the use of a drag device to dissipate energy, deviations from the speed for best L/D, and variations in ground track. In general, an approach is planned so extra altitude must be dissipated because it is much easier to dissipate extra energy than it is to conserve minimum energy. For example, if the pattern is entered with very low energy at low key, there is no choice but to fly at or near maximum L/D in order to reach final approach with enough altitude to push-over and accelerate to an acceptable flare airspeed. In summary, a pattern entered with enough altitude to require some energy dissipation is the most comfortable and the most accurate in terms of touchdown control.

8.4.3.1 DATA REQUIRED

For each of the key checkpoints in the pattern define:

1. Configuration.
2. Altitude.
3. Airspeed.
4. Position with respect to the intended point of landing.
5. Wind corrections.
6. Weight corrections.

8.4.3.2 TEST CRITERIA

1. Balanced (ball centered) wings level, unaccelerated flight.
2. Engine bleed air system OFF - or operated in a normal flight mode.
3. Stabilized engine thrust/power setting.
4. Altimeter: 29.92, standby.

8.4.3.3 DATA REQUIREMENTS

For each of the checkpoints in the pattern:

1. $H_{P_o} \pm 20$ ft.
2. $V_o \pm 5$ kn.

8.4.3.4 SAFETY CONSIDERATIONS

1. With a high rate of descent, plan for the point in the approach where a flare must be initiated to safely arrest the descent rate.
2. Don’t get slow (check deceleration).
3. Don’t get low (check rate of descent).
4. Maintain a good lookout.
5. Don’t exceed main gear loads on touchdown.
6. Watch structural loads (airspeed/g) in the landing configuration.
7. Don’t exceed tire speed limits.
8. Avoid operating characteristic limits.

Before testing precautionary/flameout approach patterns, review the current OPNAVINST 3710.7 Series (General Flight and Operating Instructions) and obtain a waiver if required.

Currently, Paragraph 542 of OPNAVINST 3710.7N states:

1. FLAMEOUT APPROACHES. Actual flameout approaches shall not be attempted unless it is impossible/impracticable to abandon the aircraft.
2. SIMULATED FLAMEOUT APPROACHES. Simulated flameout approaches are prohibited.

8.5 DATA REDUCTION

8.5.1 SAWTOOTH DESCENT

Various computer programs can assist in reducing performance data. This section contains a brief summary of the assumptions and logic which might be used. The treatment is purposefully generic as programs change over time and new ones are introduced. Detailed instructions for the particular computer or program are assumed to be available.

The purpose of the sawtooth descent data reduction program is to calculate rate and angle of descent for any given gross weight, altitude, and temperature based on flight test data.

From a menu selection, the appropriate choice is made to enter the sawtooth descent program. Data entry requirements for the program are as follows:

1. Basic data:
    a. Type of aircraft.
    b. Bureau number.
    c. Standard gross weight.
    d. Target altitude.
    e. Date of tests.
    f. Pilot’s name.
    g. Miscellaneous as allowed by the program.

2. For each data point:
    a. Initial indicated pressure altitude (ft).
    b. Final indicated pressure altitude (ft).
    c. Time required (s).
    d. Indicated airspeed (kn).
    e. OAT (˚C) or ambient temp (˚K).
    f. Fuel flow (lb/h).
    g. Gross weight (lb).
    h. Optional data as allowed by the program.

The program calculates rate and angle of descent for any weight, altitude and temperature condition. One method used is to calculate specific excess power (P_S) for each descent then correct P_S to the desired flight condition using the standard P_S correction formula.

The program calculates P_S for each data point (each descent), corrects P_S to the weight, altitude and temperature which was initially specified and calculates the resulting rate and angle of descent assuming constant calibrated airspeed (V_C) (Figures 8.10 and 8.11).

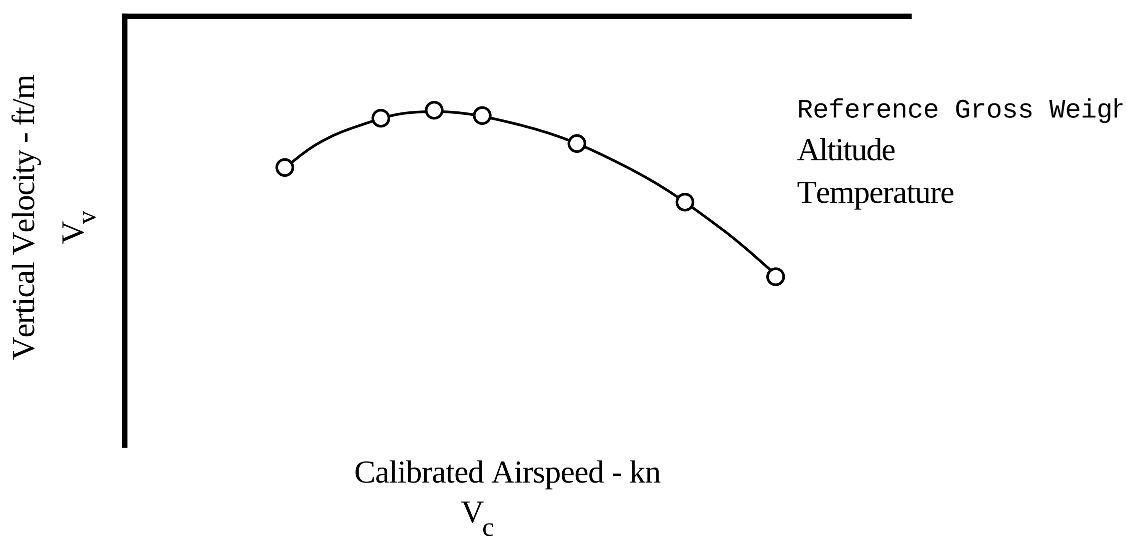


Figure 8.10

RATE OF DESCENT VERSUS CALIBRATED AIRSPEED

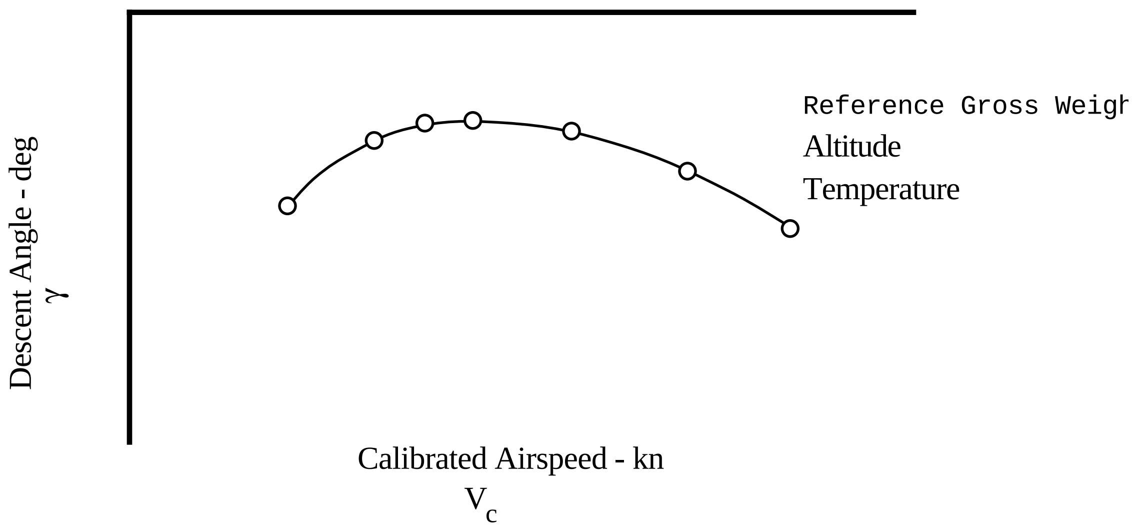


Figure 8.11
DESCENT ANGLE VERSUS CALIBRATED AIRSPEED

After these plots have been generalized, usually the ambient conditions can be changed (weight, altitude, temperature) and the data reduction can be repeated.

Another feature of the computer program is to correlate rate of descent and descent angle with angle of attack. Example figures 8.12 and 8.13 could be used to determine if there is an optimum angle of attack for the specified configuration. Generally also available from sawtooth descent data would be P_S plots vs Mach for the desired ambient conditions.

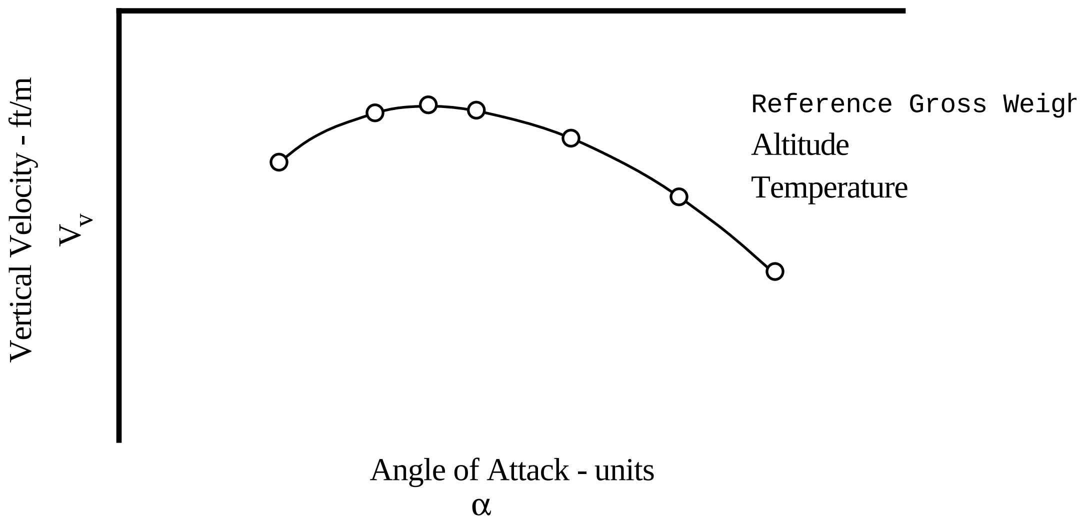


Figure 8.12
RATE OF DESCENT VERSUS ANGLE OF ATTACK

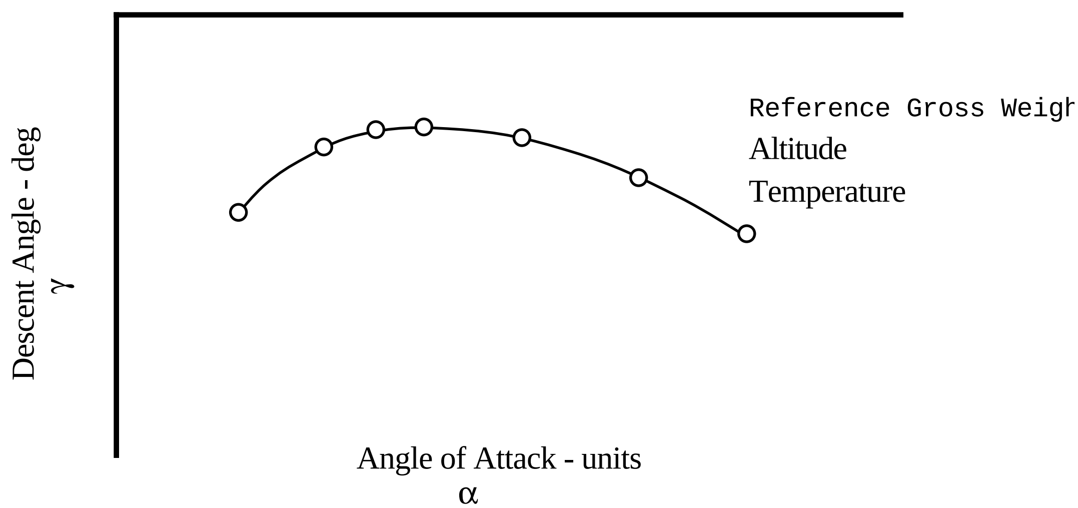


Figure 8.13
DESCENT ANGLE VERSUS ANGLE OF ATTACK

Equations used by the computer data reduction routine.

$$V_c = V_i + \Delta V_{pos} \qquad \text{(Eq 8.25)}$$

$$H_{P_c} = H_{P_i} + \Delta H_{pos} \qquad \text{(Eq 8.26)}$$

If ambient temperature (˚K) was entered:

$$T_a(°C) = T_a\,(°K) - 273.15 \qquad \text{(Eq 8.27)}$$

$$OAT = f\left(T_a, M_T\right) \qquad \text{(Eq 8.28)}$$

If ambient temperature (˚C) was entered:

$$T_a = f\,\left(OAT, M_T\right) \qquad \text{(Eq 8.29)}$$

Test data true airspeed:

$$V_{T_{Test}} = f\left(V_c, H_{P_c}, T_a\right) \qquad \text{(Eq 8.30)}$$

Standard day true airspeed:

$$V_{T_{Std}} = f\left(V_c, H_{P_c}, T_{Std}\right) \qquad \text{(Eq 8.31)}$$

First data point as $H_{P_{c\,ref}}$:

$$h = H_{P_{c\,ref}} + \Delta H_{P_c}\left(\frac{T_a}{T_{Std}}\right) \qquad \text{(Eq 8.32)}$$

Energy height:

$$E_h = h + \frac{V_{T_{Test}}^2}{2g} \quad \text{(Eq 8.33)}$$

Test data P_s (from faired E_h versus time curve):

$$P_{s_{Test}} = \frac{dE_h}{dt} \quad \text{(Eq 8.34)}$$

Standard day P_s:

$$P_{s_{Std}} = P_{s_{Test}} \left(\frac{W_{Test}}{W_{Std}} \right) \left(\frac{V_{T_{Std}}}{V_{T_{Test}}} \right) + \left(\frac{V_{T_{Std}}}{W_{Std}} \right) (\Delta T_{N_x} - \Delta D) \quad \text{(Eq 8.35)}$$

Test day flight path angle (dh/dt from the curve of h versus time):

$$\gamma_{Test} = \sin^{-1} \left[\frac{dh/dt}{V_{T_{Test}}} \right] \quad \text{(Eq 8.36)}$$

$(dh/dt)_{Std}$ is calculated from P_s based on (dV_T/dh) equivalent to constant V_c at standard conditions when $dV_T/dt \neq 0$. Apply descent correction factor (DCF):

$$DCF = 1 + \left(\frac{V_{T_{Std}}}{g} \frac{dV_T}{dh} \right) \quad \text{(Eq 8.37)}$$

$$\left(\frac{dh}{dt} \right)_{Std} = \frac{P_{s_{Std}}}{DCF} \quad \text{(Eq 8.38)}$$

Standard day flight path angle:

$$\gamma_{Std} = \sin^{-1} \left[\frac{(dh/dt)_{Std}}{V_{T_{Std}}} \right] \quad \text{(Eq 8.39)}$$

Where:

ΔD	Standard drag minus test drag	lb
ΔH_{pos}	Altimeter position error	ft
ΔT_{N_x}	Standard net thrust parallel flight path minus test net thrust	lb
ΔV_{pos}	Airspeed position error	kn
DCF	Descent correction factor	
E_h	Energy height	ft
g	Gravitational acceleration	ft/s^2
γ_{Std}	Standard flight path angle	deg
γ_{Test}	Test flight path angle	deg
H_{P_c}	Calibrated pressure altitude	ft
$H_{P_{c\ ref}}$	Reference calibrated pressure altitude	ft
H_{P_i}	Indicated pressure altitude	ft
M_T	True Mach number	
OAT	Outside air temperature	˚C or ˚K
$P_{s_{Std}}$	Standard specific excess power	ft/s
$P_{s_{Test}}$	Test specific excess power	ft/s
t	Time	s
T_a	Ambient temperature	˚C or ˚K
T_i	Indicated temperature	˚C or ˚K
T_{Std}	Standard temperature	˚C or ˚K
V_c	Calibrated airspeed	kn
V_i	Indicated airspeed	kn
V_T	True airspeed	kn or ft/s
$V_{T_{avg}}$	Average true airspeed	kn or ft/s
$V_{T_{Std}}$	Standard true airspeed	kn or ft/s
$V_{T_{Test}}$	Test true airspeed	kn or ft/s
W_{Std}	Standard weight	lb
W_{Test}	Test weight	lb.

8.5.2 CHECK DESCENT

Descent data for an idle thrust descent is generally presented using test day weight and atmospheric conditions. For a more exact analysis, the rate of descent can be corrected to a standard gross weight. For tests conducted with all engines operating normally, corrections to thrust are generally not considered during the data reduction. However, for tests performed to establish the criteria for engine-out descents, a correction for thrust would be required.

The following equations are used in the data reduction:

$$V_i = V_o + \Delta V_{ic} \qquad \text{(Eq 8.40)}$$

$$V_c = V_i + \Delta V_{pos} \qquad \text{(Eq 8.25)}$$

$$H_{P_i} = H_{P_o} + \Delta H_{P_{ic}} \qquad \text{(Eq 8.41)}$$

$$H_{P_c} = H_{P_i} + \Delta H_{pos} \qquad \text{(Eq 8.26)}$$

$$T_i = T_o + \Delta T_{ic} \qquad \text{(Eq 8.42)}$$

$$V_T = 39.0\ M \sqrt{T_a\ (°K)} \qquad \text{(Eq 8.43)}$$

$$W_{f_{Used}} = W_{f_{Start}} - W_{f_{End}} \qquad \text{(Eq 8.44)}$$

$$\Delta d = V_{T_{avg}} \frac{\Delta t}{60} \qquad \text{(Eq 8.45)}$$

$$\text{Range} = \sum_{\text{Sea Level}}^{H_P} \Delta d \qquad \text{(Eq 8.46)}$$

Where:

d	Distance	nmi or ft
$\Delta H_{P_{ic}}$	Altimeter instrument correction	ft
ΔH_{pos}	Altimeter position error	ft
ΔT_{ic}	Temperature instrument correction	˚C or ˚K
ΔV_{ic}	Airspeed instrument correction	kn
ΔV_{pos}	Airspeed position error	kn
H_P	Pressure altitude	ft
H_{P_c}	Calibrated pressure altitude	ft
H_{P_i}	Indicated pressure altitude	ft
H_{P_o}	Observed pressure altitude	ft
M	Mach number	
θ	Temperature ratio	
t	Time	s
T_a	Ambient temperature	˚C or ˚K
T_i	Indicated temperature	˚C or ˚K
T_o	Observed temperature	˚C or ˚K
V_c	Calibrated airspeed	kn
V_i	Indicated airspeed	kn
V_o	Observed airspeed	kn
V_T	True airspeed	kn or ft/s
$V_{T_{avg}}$	Average true airspeed	kn or ft/s
$W_{f_{End}}$	End fuel weight	lb
$W_{f_{Start}}$	Start fuel weight	lb
$W_{f_{Used}}$	Fuel used	lb.

From the observed data compute as follows:

Step	Parameter	Notation	Formula	Units	Remarks
1	Indicated airspeed	V_i	Eq 8.40	kn	
2	Calibrated airspeed	V_c	Eq 8.25	kn	
3	Indicated pressure altitude	H_{P_i}	Eq 8.41	ft	
4	Calibrated pressure altitude	H_{P_c}	Eq 8.26	ft	
5	Mach number	M			From Appendix VI
6	Indicated temperature	T_i	Eq 8.42		
7	Ambient temperature	T_a			From Appendix VI
8	True airspeed	V_T	Eq 8.43	kn	
9	Fuel used	$W_{f_{Used}}$	Eq 8.44	lb	
10	Distance	d	Eq 8.45	nmi	
11	Range	Range	Eq 8.46	nmi	

Construct a graph of H_{P_c} versus time to descend. Fair a smooth curve through the data and extrapolate to sea level (Figure 8.14).

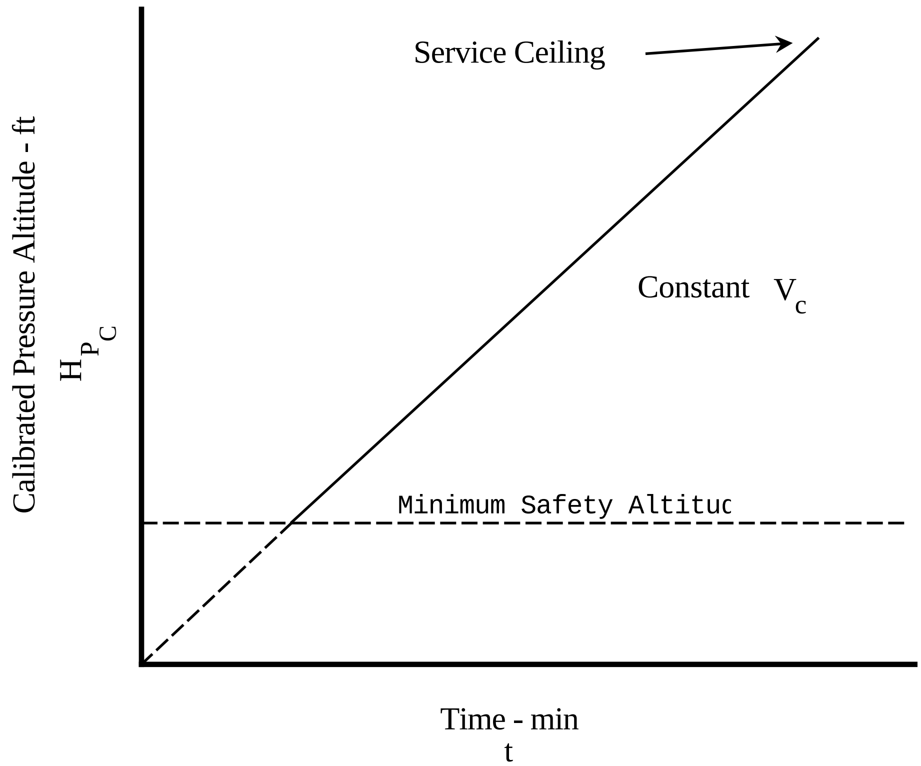


Figure 8.14

CALIBRATED PRESSURE ALTITUDE VERSUS TIME TO DESCEND

Construct a graph of H_{P_c} versus fuel used in the descent. Fair a smooth curve through the data and extrapolate to sea level (Figure 8.15).

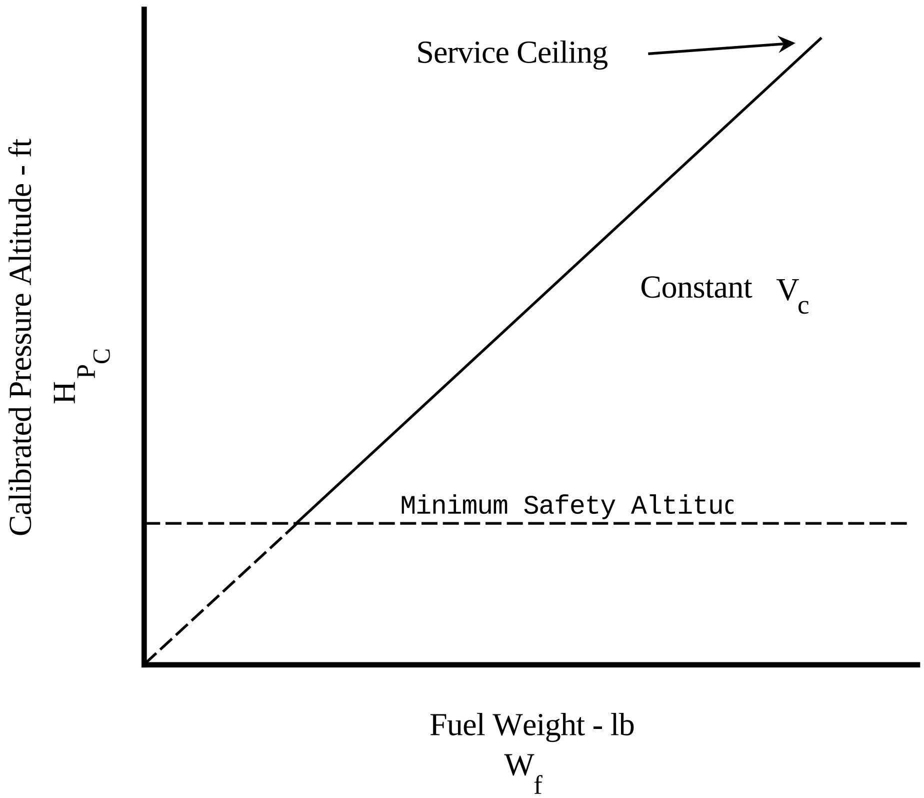


Figure 8.15
CALIBRATED PRESSURE ALTITUDE VERSUS FUEL USED IN THE DESCENT

From figure 8.14, graphically measure the indicated rate of descent (dH_{P_c}/dt) at appropriate intervals beginning at the service ceiling. Construct a table for each test airspeed and interval measured (Figure 8.16).

Altitude ft	Time, Δt s	dh/dt ft/s	V_T ft/s	Glide Ratio $\frac{V_T}{dh/dt}$
From top of test altitude (service ceiling) to minimum safe altitude in 2 to 5,000 ft increments				

Figure 8.16
RATE OF DESCENT AND GLIDE RATIO

Using figure 8.16, construct a graph of the variation of pressure altitude with distance traveled during the descent (Figure 8.17).

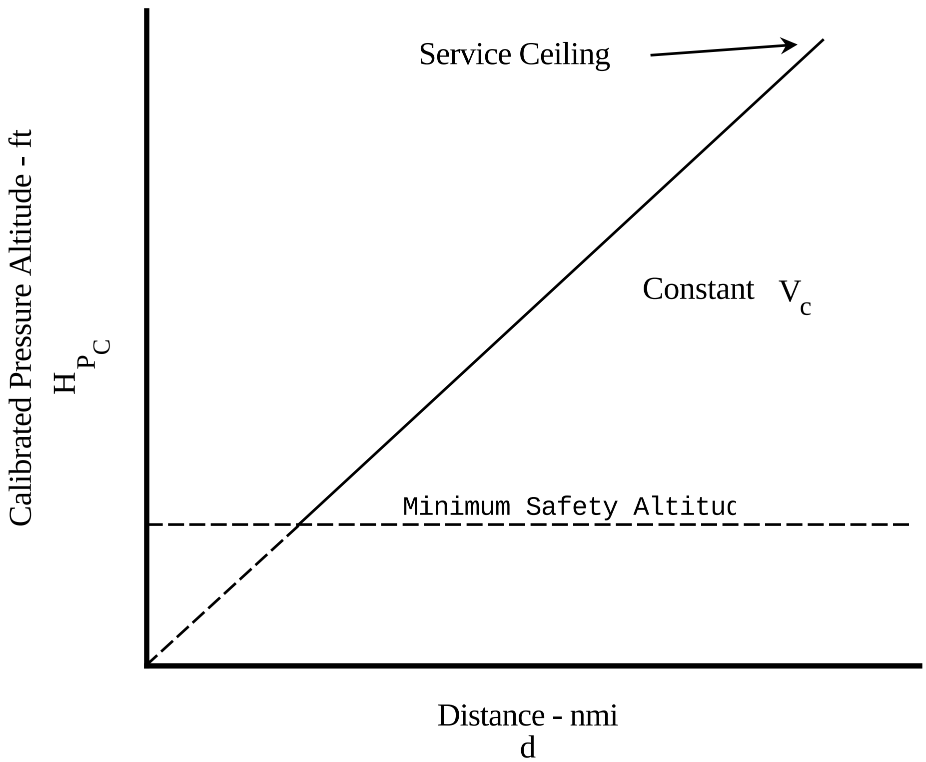


Figure 8.17

CALIBRATED PRESSURE ALTITUDE VERSUS DISTANCE TRAVELED DURING THE DESCENT

Combining figures 8.14, 8.15, and 8.17, the results can be presented either as a table or as a plot of time, fuel used, and distance for an idle descent from the service ceiling to sea level (Figure 8.18).

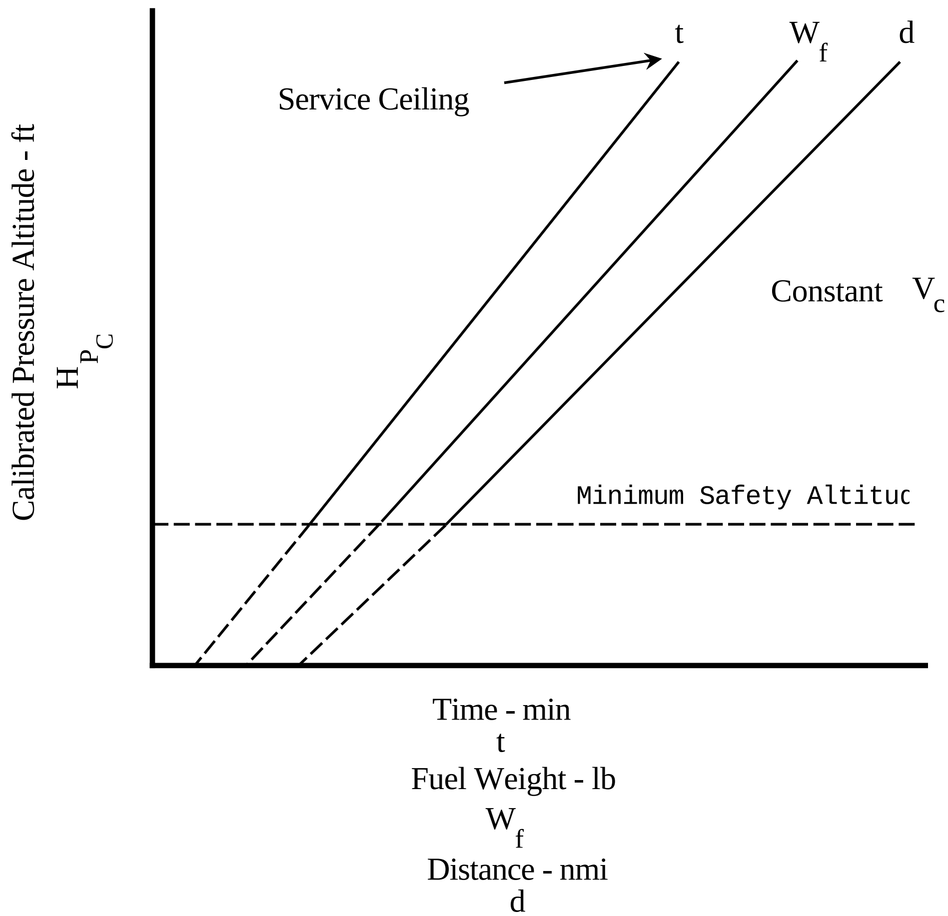


Figure 8.18

CALIBRATED PRESSURE ALTITUDE VERSUS TIME, FUEL USED, AND DISTANCE DURING THE DESCENT

Once this same data has been accumulated for several calibrated airspeeds (V_c), a family of V_c curves can be plotted (Figure 8.19).

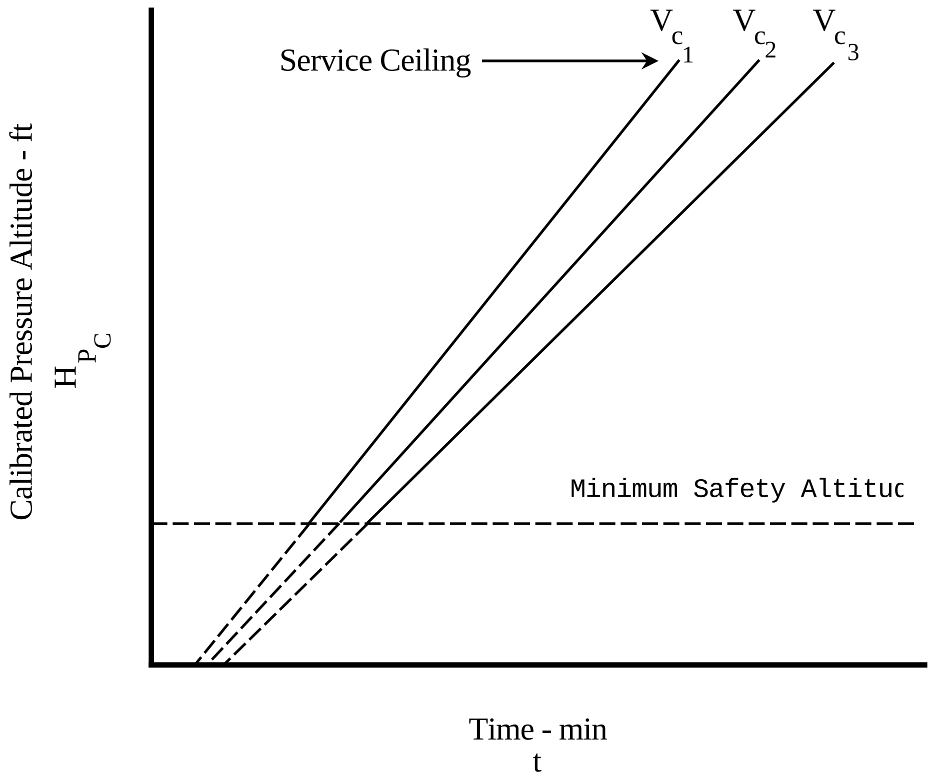


Figure 8.19

DESCENT PERFORMANCE, CALIBRATED PRESSURE ALTITUDE VERSUS TIME FOR A FAMILY OF CALIBRATED AIRSPEEDS

Combining the glide ratio data from figure 8.16, obtained for each test V_C, and for each altitude, a plot of airspeed versus glide ratio can be made (Figure 8.20).

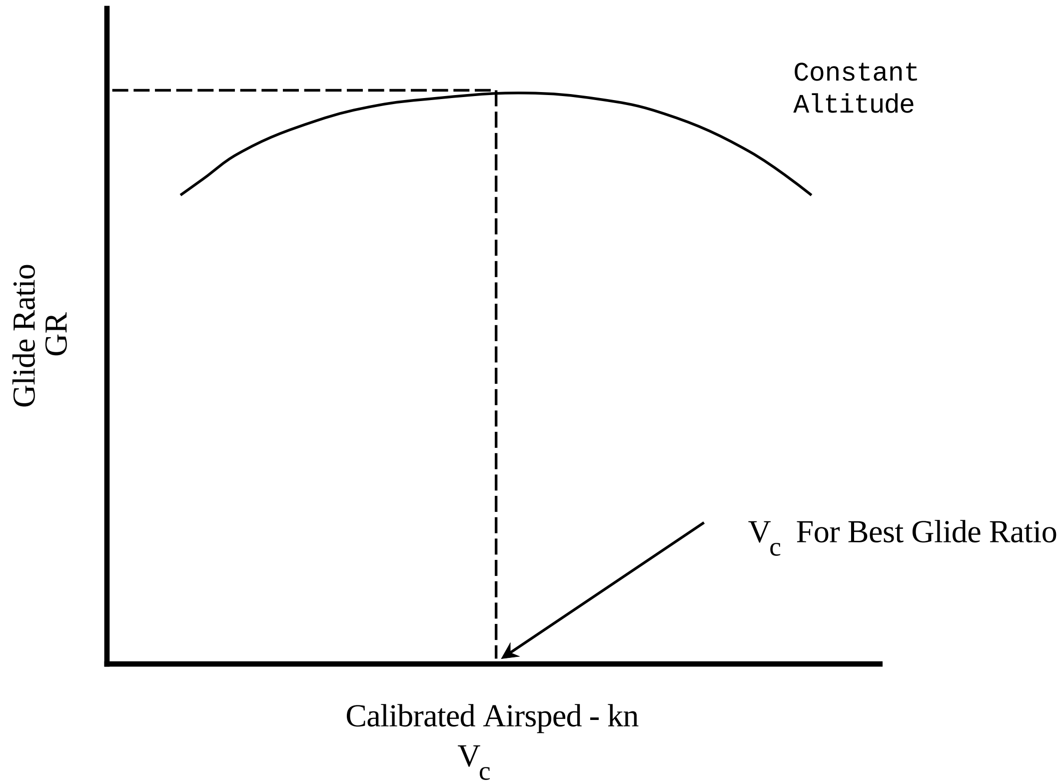


Figure 8.20
AIRSPEED VERSUS GLIDE RATIO

Taking the value for best glide ratio at each altitude, the plot in figure 8.21 is constructed to determine the optimum descent schedule.

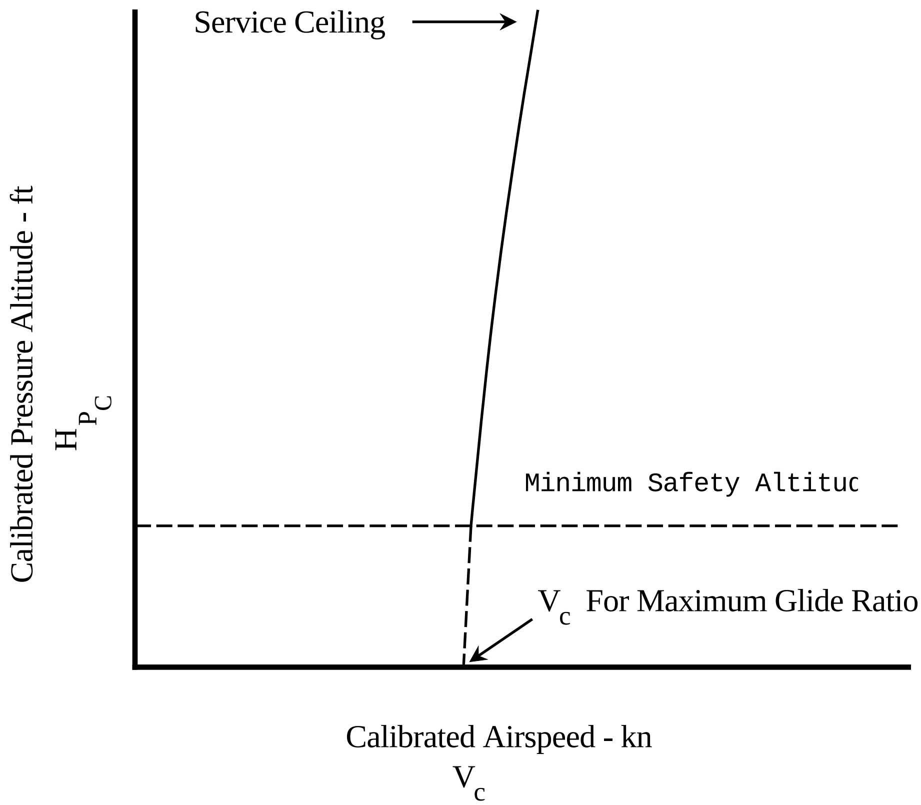


Figure 8.21
OPTIMUM DESCENT SCHEDULE

8.6 DATA ANALYSIS

The analysis of descent data is directed toward determining the optimum descent schedules to provide maximum range for fuel used for various configurations. Usually the difference in V_c is not great enough to warrant publishing a schedule; usually a best compromise V_c is specified.

Another aspect of the data analysis is to determine how sensitive the selected descent airspeed is to deviations on both the fast and slow side. For example, what percentage of the maximum range can be achieved if the aircraft is flown 20 kn faster than the recommended descent airspeed?

8.7 MISSION SUITABILITY

8.7.1 DESCENT PERFORMANCE

Mission suitability conclusions concerning descent performance are not restricted to optimum performance test results. Test results reflect the performance capabilities of the aircraft while mission suitability conclusions include the flying qualities and systems performance associated with specific airspeeds/thrust/power levels. Consideration of the following items is worthwhile when evaluating descent performance:

1. Field of view.
2. Mission profile requirement.
3. Compatibility of airspeed with the mission and location restrictions.
4. Performance sensitivity for altitude or airspeed deviation.
5. System performance:
   a. Pressurization.
   b. Anti-ice.
   c. Cockpit temperature.

8.7.2 PRECAUTIONARY/FLAME OUT APPROACH

Evaluating precautionary and flameout approaches depend upon the answers to the following questions:

1. Under what circumstances would a precautionary or flameout approach be recommended?
2. What training would be required for pilots to successfully complete the approach?
3. What is the pattern sensitivity to airspeed or altitude deviations?

8.8 SPECIFICATION COMPLIANCE

Generally, there are no specification compliance requirements against which the descent performance of an airplane must be demonstrated. Specifically, in NAVAIRSYSCOM Specification, AS-5263, which defines the requirements for performance data and mission profiles, the assumption used for the descent phase is no fuel is consumed and no distance is covered.

An exception exists for propeller airplanes with a published STOL performance achieved by using a beta range of propeller blade angle for the steep descent flight path. In this case, the rates of descent and correct beta blade angles need to be checked against the STOL performance guarantee.

8.9 GLOSSARY

8.9.1 NOTATIONS

AGL	Above ground level	
d	Distance	nmi or ft
ΔD	Standard drag minus test drag	lb
DCF	Descent correction factor	
$\Delta H_{P_{ic}}$	Altimeter instrument correction	ft
ΔH_{pos}	Altimeter position error	ft
ΔT_{ic}	Temperature instrument correction	˚C or ˚K
ΔT_{N_x}	Standard net thrust parallel flight path minus test net thrust	lb
ΔV_{ic}	Airspeed instrument correction	kn
ΔV_{pos}	Airspeed position error	kn
E_h	Energy height	ft
FOD	Foreign object damage	
F_x	Forces parallel to flight path	lb
F_z	Force perpendicular to flight path	lb
g	Gravitational acceleration	ft/s^2
GR	Glide ratio	
h	Tapeline altitude	ft
H_P	Pressure altitude	ft
H_{P_c}	Calibrated pressure altitude	ft
$H_{P_{c\,ref}}$	Reference calibrated pressure altitude	ft
H_{P_i}	Indicated pressure altitude	ft
H_{P_o}	Observed pressure altitude	ft
L	Lift	lb

M	Mach number	
M_T	True Mach number	
OAT	Outside air temperature	˚C or ˚K
$P_{s_{Std}}$	Standard specific excess power	ft/s
$P_{s_{Test}}$	Test specific excess power	ft/s
ROD	Rate of descent	ft/s
t	Time	s
T_a	Ambient temperature	˚C or ˚K
T_i	Indicated temperature	˚C or ˚K
T_o	Observed temperature	˚C or ˚K
T_{Std}	Standard temperature	˚C or ˚K
V_c	Calibrated airspeed	kn
V_{hor}	Horizontal velocity	kn or ft/s
V_i	Indicated airspeed	kn
V_o	Observed airspeed	kn
V_T	True airspeed	kn or ft/s
$V_{T_{avg}}$	Average true airspeed	kn or ft/s
$V_{T_{Std}}$	Standard true airspeed	kn or ft/s
$V_{T_{Test}}$	Test true airspeed	kn or ft./s
V_v	Vertical velocity	ft/s
W	Weight	lb
W_f	Fuel weight	lb
$W_{f_{End}}$	End fuel weight	lb
$W_{f_{Start}}$	Start fuel weight	lb
$W_{f_{Used}}$	Fuel used	lb
W_{Std}	Standard weight	lb
W_{Test}	Test weight	lb
$\dot{W}_f$	Fuel flow	lb/h

8.9.2 GREEK SYMBOLS

α (alpha)	Angle of attack	deg
γ (gamma)	Flight path angle	deg
γ_{Std}	Standard flight path angle	deg
γ_{Test}	Test flight path angle	deg

θ (theta) Temperature ratio

8.10 REFERENCES

1. Dommasch, D.O et al, *Airplane Aerodynamics*, 4th Edition, Pitman Publishing Company, N.Y., N.Y., 1967.

2. HP Model 9816 Computer System, “USNTPS Fixed Wing Aircraft Performance User Instructions”, March 1985.

3. NAVAIRSYSCOM Specification, AS-5263, “Guidelines for Preparation of Standard Aircraft Characteristics Charts and Performance Data, Piloted Aircraft (Fixed Wing)”, 23 October 1986.

4. Naval Test Pilot School Flight Test Manual, *Fixed Wing Performance, Theory and Flight Test Techniques*, USNTPS-FTM-No. 104, U.S. Naval Test Pilot School, Patuxent River, MD, July 1977.

5. OPNAVINST 3710.7N, “NATOPS General Flight and Operating Instructions”, 25 August, 1992.

6. Peterson, *Aircraft and Engine Performance*, USNTPS Textbook, USNTPS, Patuxent River, MD, 1958.

7. Powell, J.W., *Airplane Performance, Fixed Wing Flight Mechanics*, USNTPS Class Notes, USNTPS, Patuxent River, MD, undated.

8. Stinton, D., *The Design of the Aeroplane*, Van Nostrand Reinhold Company, N.Y.

9. USAF Test Pilot School Flight Test Manual, *Performance Flight Testing Phase*, Volume I, USAF Test Pilot School, Edwards AFB, CA, February 1987.