

---

# Helicopter performance

---



# Contents

<b>Some accident examples .....</b>	<b>5</b>	Decision points .....	23
<b>PIC responsibilities .....</b>	<b>7</b>	Speed control .....	24
How to comply .....	7	Overpitching .....	24
<b>Performance factors.....</b>	<b>8</b>	Pilot technique .....	25
Weight .....	8	Vortex ring state .....	25
Air density .....	9	Rotor condition .....	26
Wind .....	15	Contingencies.....	26
Ground effect.....	18	Know your helicopter .....	26
Slope .....	20	<b>Determining performance.....</b>	<b>27</b>
Surface .....	20	Examples .....	27
<b>Other considerations.....</b>	<b>21</b>	<b>Conclusion .....</b>	<b>33</b>
Power checks.....	21	Performance questions.....	34

## Abbreviations

<b>AMSL</b>	Above mean sea level
-------------	----------------------

<b>FATO</b>	Final approach and take-off
-------------	-----------------------------

<b>hPa</b>	Hectopascals
------------	--------------

<b>HPA</b>	Available horsepower
------------	----------------------

<b>HPR</b>	Required horsepower
------------	---------------------

<b>IGE</b>	In ground effect
------------	------------------

<b>ISA</b>	International Standard Atmosphere
------------	-----------------------------------

<b>MAP</b>	Manifold absolute pressure
------------	----------------------------

<b>OGE</b>	Out of ground effect
------------	----------------------

<b>P alt</b>	Pressure altitude
--------------	-------------------

<b>QNH</b>	An altimeter sub-scale setting to obtain elevation when on the ground
------------	---

<b>TAS</b>	True airspeed
------------	---------------

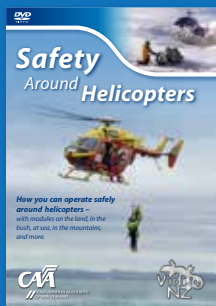
<b>TLOF</b>	Touchdown and lift-off area
-------------	-----------------------------

**Cover photo:** Courtesy of Neville Dawson/www.heliopsmag.com

### Acknowledgements:

The technical assistance provided by North Shore Helicopters, Kapiti Districts Aero Club, Garden City Helicopters, Ardmore Helicopters and Canterbury Helicopters in compiling this booklet is gratefully acknowledged.

Every effort is made to ensure the information in this booklet is accurate and up-to-date at the time of publishing, but numerous changes can occur with time, especially in regard to airspace and legislation. Readers are reminded to obtain appropriate up-to-date information.



### Safety Around Helicopters

This DVD is ideal for your passenger safety briefings because it is designed for everyone who works around helicopters, especially non-aviation passengers. The Introduction has information for everyone, and there are separate modules on: Industry; Going Bush; Corporate and Tourism; The Mountains; Rescue on the Land; All at Sea; and Helicopter Identification.

You can order your copy from Video New Zealand: [www.videonz.co.nz](http://www.videonz.co.nz)

See the CAA website for Civil Aviation Rules, advisory circulars, airworthiness directives, forms, and more safety publications. Visit [aviation.govt.nz](http://aviation.govt.nz).

Photo courtesy of Neville Dawson/[www.helicoptersmag.com](http://www.helicoptersmag.com)



It's worth considering that when descending below a treeline to land, the assisted wind and increase in temperature below the treeline will degrade aircraft performance.



A significant number of New Zealand helicopter accidents are performance-related. Most of them occur during take-off or landing – the remainder are associated with external load or confined-area operations.

The circumstances of the performance-related accidents usually indicate the pilot had not ensured there was sufficient power available for the intended manoeuvre in the prevailing conditions.

This booklet examines the factors affecting performance and provides guidance to help pilots ensure that a proposed operation can be safely accomplished.

Many of these accidents occurred when the helicopters were being operated from sites that were elevated, facing out of wind, restricted by terrain, sloping, or had rough surfaces. In most cases the sites were on ridge tops or in confined, steep-sided valleys. Often the helicopters were being operated at high

gross weights, in higher ambient temperatures and lower air pressures than standard.

These accidents could have been prevented had the pilots been fully aware of the prevailing conditions, and taken the time to determine the performance capabilities of their helicopter before committing themselves. Such accident prevention relies on thorough pre-flight preparation, of which flight manual performance chart calculations are an integral part. Because the ambient conditions at the intended point of operation can be quite different from those planned for, and because flight manual performance graphs can sometimes be optimistic, calculated values must always be validated by an actual power check at the operating site.

# Some accident examples

The following examples illustrate how a series of events can compound to result in an accident in which a lack of performance becomes a key causal factor. Although we've used piston-engine examples here, gas-turbine powered helicopters are also susceptible to performance problems.

## Insufficient power

The purpose of the Robinson R22B helicopter flight was to land a passenger by the south side of a small lake at 5300 feet above mean sea level (AMSL). A small tramping pack was carried on the cargo hook.

The only clear approach was from the south, and a missed approach was not practicable from late final. A high reconnaissance was flown and a landing point selected on a knoll. A power check suggested that a hover landing should be possible, and the lake surface indicated no wind.

On short final the pilot found that the helicopter did not slow as intended. After losing translational lift, the rotor rpm started to decay, and the descent was not arrested.

The pilot turned the helicopter away from the knoll toward lower but uneven ground, in an effort to make a controlled landing. The ensuing heavy landing collapsed the left skid gear and the helicopter rolled over.

The pilot applied full carburettor heat after he had reduced power for the approach, but he didn't return the control to the COLD position before landing. A subsequent flight check in the area showed that this reduced the available manifold absolute pressure (MAP) by half an inch.

The hook load was not jettisoned.



## Analysis

For the conditions at the time, the flight manual indicated that the R22B could accomplish an out of ground effect (OGE) hover at 5300 ft AMSL with the two persons and hook load on board, but it seems from events that the margins were small. The loss of MAP from having carburettor heat selected, together with a possible light tailwind, presumably tipped the balance.

The situation would have deteriorated fairly rapidly, but by jettisoning the cargo hook load the pilot might have restored the balance enough to prevent the accident.





## Too high

A tramper who wished to be flown to a hut in the mountains, approached a helicopter operator advising him that the hut was at an elevation of 1450 feet AMSL. The pilot assigned to the job flew the Robinson R22B to the airport where the tramper waited.

The pilot assessed the weight of the tramper, pack, helicopter, and fuel and considered them to be within the capability of the helicopter to operate at the elevation of the hut. Some items from the tramper's pack were stowed under the seat, and the pack was placed at his feet. The pilot did an IGE hover check, and found that 24 inches of MAP was required for the hover.

The tramper guided the pilot to the hut, which turned out to be at a much greater height than expected. The pilot did a power check and elected to land on a nearby tussock-covered saddle. He approached the saddle obliquely to allow for an escape route, and flew the helicopter in a shallow approach at 22 inches MAP.

At about 15 feet above the landing site, the pilot noticed the rpm was at 97 percent – the bottom of the normal range – and opened the throttle fully. No more power was available, and believing a landing was inevitable, the pilot tried to control the flight path by increasing collective pitch. He could not arrest the helicopter forward motion by applying full aft cyclic, and the helicopter began to rotate, touching down heavily. The helicopter then pitched slowly onto its nose and fell onto its right side.

The tramper had misled the pilot about the correct site elevation, and used the NZMS 260 series of maps, which showed heights in metres. The altitude of the hut was 1450 metres AMSL (4750 feet), not 1450 feet as the tramper reported.

Another significant factor was the helicopter weight and balance. Using the weights the pilot estimated, the helicopter take-off weight was 635 kilograms, 13 kilograms over its maximum. This inevitably placed a premium on the power required. Moreover, by placing the pack at the tramper's feet, the helicopter was probably loaded outside its forward CG limits.

This would have added to the difficulties of using cyclic to arrest the helicopter forward motion.

Lack of a power margin was inevitable given the helicopter weight and the density altitude at the landing site, but the pilot did not recognise the shortfall in power. The pilot carried out a power check estimate as he approached the landing area, but did not apply the technique fully. Had he done so, it would have shown the power required was 24 inches MAP and the power available was 23 inches. A no-go situation would then have been evident.

After recognising that there was insufficient power available, the pilot used an incorrect recovery technique.

At 15 feet above the landing site, the helicopter could have been accelerated to about 15 knots to gain translational lift. This would have significantly reduced the power required, and the pilot could have taken time out to figure another way of delivering the tramper and his pack.

Or, the pilot could have considered the cost and complications of a potential crash compared with the cost of turning around. He could have landed in the lower ground (in the background of the picture to the left), and reassessed the job, with the possibility of using a more appropriate aircraft.

## Analysis

Overall, this flight had the odds stacked against it being successfully carried out, although there were numerous opportunities for the pilot to have rectified the situation along the way.

# PIC responsibilities

Section 13 of the Civil Aviation Act 1990 says that the pilot-in-command has the responsibility to ensure that they operate their aircraft in a safe manner with respect to performance. More specifically, rule 91.201(2) states that "A pilot-in-command of an aircraft must ... during the flight, ensure the safe operation of the aircraft and the safety of its occupants...". Rule 91.109 states, "No person shall operate an aircraft unless it is operated in compliance with the operating limitations specified in the aircraft flight manual."

## How to comply

Compliance with these rules can be achieved by using the performance data graphs contained in the helicopter flight manual. Enter the graph and trace the applicable data to determine the performance capabilities for the given conditions – and then confirm those values with a power check. Most flight manuals have graphs for determining density altitude, IGE and OGE hover ceilings, take-off distances, and rate-of-climb performance. Please note that between helicopter types there is considerable variation in the standard of information presented in these graphs.

The use of these graphs is discussed, with worked examples, later in this booklet.



Photo courtesy of Neville Dawson/  
[www.heliopsmag.com](http://www.heliopsmag.com)

## Performance factors

In this section we discuss how various physical and environmental factors can adversely affect helicopter performance.

We have tried to avoid using rule-of-thumb methods for determining performance, because there are differences between helicopter types – the application of rules-of-thumb could be misleading. Instead, we have given a number of performance examples from a range of helicopter types to illustrate how each performance factor affects performance capability. Refer to your helicopter flight manual or operating procedures, or ask your chief pilot or instructor for the specific performance information that applies to your helicopter.

Please note that the performance values derived for the following examples may be significantly better than what the helicopter can actually achieve. They are based on a brand new helicopter (ie, with an 'on spec' engine, clean rotor blades, and a helicopter that is correctly rigged)

being flown by an experienced test pilot; they often tend to be optimistic.

Bear in mind that engine performance may deteriorate between overhaul periods. All examples have been derived from flight manual performance graphs only, and they would normally be validated by an actual power check under the ambient conditions existing at the point of intended operation.

Some flight manuals contain performance charts that have minor variations (eg, generator ON, sand filter fitted, bleed air ON, etc). You must use the correct variant so that accurate performance data is obtained.

### Weight

What can be seen is that the greater the gross weight of the helicopter, the greater the lift (rotor thrust) required for hovering



or climbing. The available lift is proportional to the collective setting and the associated rotor blade angle of attack. The power available determines the maximum collective pitch setting that can be maintained at the optimum rotor rpm. The heavier the helicopter the greater the power required to hover (and for flight in general), and the smaller the margin between the power required and the power available. The higher the gross weight the lower the hover ceiling, and therefore the more restricted the helicopter will be in where it can operate. This can be seen from the following two examples.

### Effect of increasing weight on IGE hover ceiling example: Schweizer 269C

<b>Gross weight</b>	725 kg	910 kg
<b>Temperature</b>	+27°C at sea level	+27°C at sea level
<b>QNH</b>	1003 hPa	1003 hPa
<b>Hover ceiling</b>	11,350 feet P alt (1013 hPa set)	5400 feet P alt (1013 hPa set)
<b>Which gives</b>	11,050 feet indicated alt (QNH set)	5100 feet indicated alt (QNH set)

Pilots must ensure that they always use an established method to accurately determine the gross weight of the helicopter prior to flight. This means totalling the weights of the crew, passengers, fuel and any other items being carried in a systematic way, which will allow accurate performance calculations to be carried out. A check of the power required to hover IGE can then be made to confirm that the actual weight of the helicopter corresponds to this figure. Many Flight manuals have graphs to help determine this.

## Air density

As air density decreases, both engine (particularly normally aspirated piston-engines) and aerodynamic performance (rotor thrust) decrease.

### *Effect of pressure on density*

Atmospheric pressure decreases with increasing altitude, because the air near the earth's surface is compressed by the air above it. The reduced pressure allows the air to expand and to become less dense as a result.

### *Effect of temperature on density*

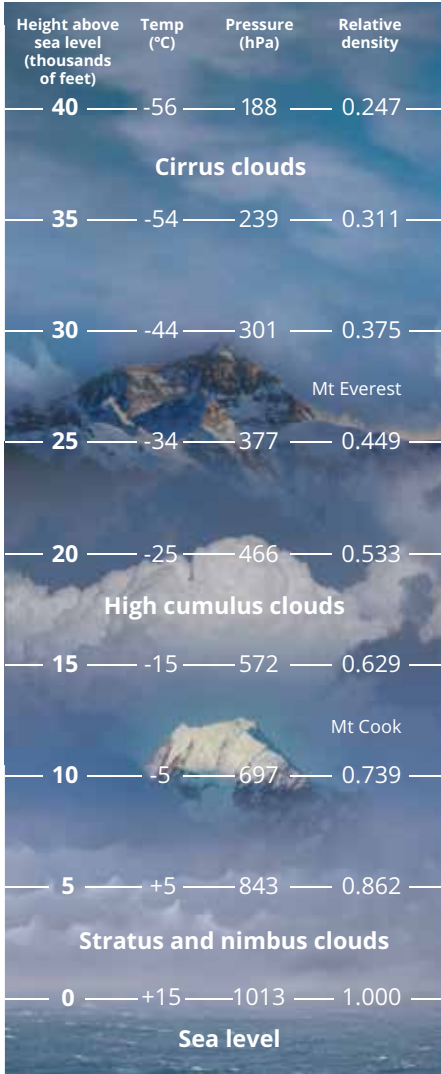
Temperature generally decreases with altitude. This makes the air contract and become denser. However, the pressure reduction of increasing altitude has the greater effect, over the increase in density from the reduction in air temperature.

### *Effect of humidity on density*

Unfortunately there is no general formula that allows a pilot to calculate the effect of humidity, although some helicopter manufacturers provide graphs for determining performance in high-humidity conditions. Pilots must develop a keen sense of moisture assessment, and expectations of the helicopter performance must be adjusted accordingly. Hot and humid conditions usually bring about reduced engine (and aerodynamic) performance and reduced lift – factors that should never be underestimated when operating at high density altitudes and gross weights.

**Figure 1:**

International Standard Atmosphere



### International Standard Atmosphere

An International Standard Atmosphere (ISA) has been established to enable comparison of aircraft performance, calibration of altimeters, and other practical uses.

In the ISA, a particular pressure and temperature distribution with height is assumed. At sea level the pressure is taken to be 1013.2 hPa, and the temperature 15°C. ISA also assumes dry air.

### Pressure altitude

In ISA, any pressure level has a standard corresponding altitude called the pressure altitude, based on a lapse rate of approximately one hPa per 30 feet at lower levels. Pressure altitude is the height that will register on a sensitive altimeter whenever its sub-scale is set to 1013.2 hPa.

At any ISA pressure level, there is also a corresponding temperature called the *ISA temperature*. In ISA, temperature falls off with height at a rate of 1.98°C per 1000 feet up to 36,090 feet, above which it is assumed to be constant (see Figure 1).

Warm air is less dense than cold air. Thus, when the temperature at a given altitude is higher than the standard atmospheric temperature, the air at that altitude will be less dense.

### Density altitude

Density altitude represents the combined effect of pressure altitude and temperature.

Density altitude is defined as the height in the standard atmosphere that has a density corresponding to the density at the particular location (on the ground or in the air) at which the density altitude is being measured. Density altitude can be calculated by taking pressure altitude and adding (or subtracting)

120 feet for each 1°C above (or below) ISA. This is not something that pilots normally have to do in practice, because the temperature reference lines on a performance graph works this out for them. Pilots still need to understand how this is calculated, so see page 27 for details.

Helicopter performance is highly dependent on air density, which directly affects engine power, drag, and rotor efficiency. As air density decreases, performance decreases. Density altitude, therefore, provides a basis for relating air density to ISA, so that comparative helicopter performance can be readily determined. High density altitudes are usually found at high-elevation take-off and landing sites, particularly when the air temperature is high and the atmospheric pressure is low. Such conditions are commonly found in the Southern Alps or the Central North Island. Operating from such high density altitude sites can be perilous, so your performance calculations have to be consistently accurate.

The effect of a high density altitude on the power developed from a normally aspirated piston engine is particularly adverse,

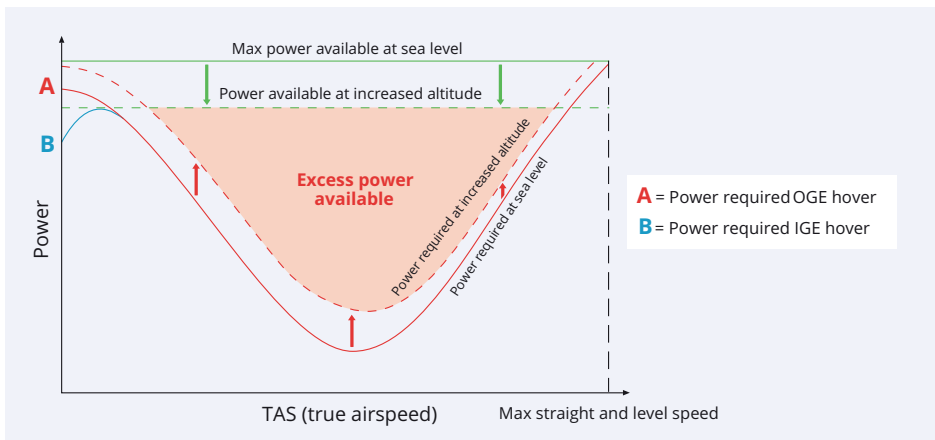
meaning that less power will be available for hovering, taking off and landing. The power available from a gas-turbine engine also falls off at a similar rate as density altitude increases. The engine may ultimately become temperature or gas producer speed limited, which will reduce its available power.

The margin between available power and the power required to hover at high gross weights and high density altitudes is often small for helicopters. Density altitude therefore becomes a lot more important to the helicopter pilot than to the fixed-wing pilot (see Figure 2).

In practical terms for the pilot, an increase in density altitude has a number of effects on helicopter performance:

- Reduced hover ceiling – means the choice of take-off and landing sites available to the pilot becomes limited.
- Reduced operating margins – means reduced payloads.
- Reduced rate-of-climb performance – means obstacle clearance can be adversely affected.

**Figure 2:** Effect of increasing altitude on HPA / HPR (available horsepower/required horsepower)



The pilot should gain as much prior knowledge as practicable of the ambient conditions at the landing site.

Photo: istockphoto.com/vollo



### Take-off

For any given weight, the higher the density altitude at the departure point, the more the power required to hover, because of reduced rotor efficiency. With engine performance already reduced, the amount of excess power available to hover can be small. Under certain conditions, a helicopter may not have sufficient power available to take off in such a way that satisfactory obstacle clearance can be assured. Limited-power techniques such as a cushion-creep or a running take-off may need to be made. Usually these are not options in a confined-area operation, because there

may be insufficient distance available, or the surface may be unsuitable. For this reason, the power required for the type of take-off and the power available to achieve it must always be carefully assessed beforehand. For power checks see page 21.

Translational lift must be achieved as soon as possible after lift-off and the helicopter accelerated to the speed for best climb angle. If not specified in the flight manual, this is approximately translational lift speed plus 20 knots (also known as best endurance or minimum power speed).



## Landing

Given that a normal landing is preceded by a hover, the limited power available at high density altitudes can be just as much of a problem when landing. If the landing site has a high density altitude, sufficient power may not be available to hover at your operating weight. In such conditions, a safe landing may be accomplished by doing a run-on or a zero-speed landing but, again, this is not always an option in a confined-space or on a rough surface.

The pilot should gain as much prior knowledge as practicable of the ambient conditions at the landing site. If relevant, allow for the fact that surface heating can cause the air temperature immediately above the landing site to be higher than the theoretical value based on the temperature of the day and the lapse rate. Before attempting the flight, calculate the hover ceiling through the use of flight manual performance graphs.

This will give the pilot some idea of what to expect. Note that the performance graphs do not take into account adverse factors such as rotor condition and ground surface type.

Near the landing site, and before a landing is attempted, the predicted hover ceiling must be confirmed with a power check. See page 21 for details.

## Some examples

The following examples illustrate the relative effects that changing temperature and pressure individually have on helicopter performance.



Headwind can be particularly useful when the helicopter is being operated at the limit of its lifting capability, such as in sling-load operations.

**Effect of increasing temperature on OGE hover ceiling example: R22B at 590 kg gross weight.**

<b>Temperature</b>	<b>-10°C</b>	<b>+10°C</b>
<b>QNH</b>	1005 hPa	1005 hPa
<b>Hover ceiling</b>	7100 feet P alt (1013 set)	5900 feet P alt (1013 set)
<b>Which gives</b>	6860 feet indicated alt (QNH set)	5660 feet indicated alt (QNH set)

**Effect of reducing atmospheric pressure on OGE hover ceiling example: R22B at 590 kg gross weight.**

<b>Temperature</b>	<b>+10°C</b>	<b>+10°C</b>
<b>QNH</b>	<b>1030 hPa</b>	<b>995 hPa</b>
<b>Hover ceiling</b>	5900 feet P alt (1013 set)	5900 feet P alt (1013 set)
<b>Which gives</b>	6410 feet indicated alt (QNH set)	5360 feet indicated alt (QNH set)

**Effect of increasing temperature on OGE hover ceiling example: AS350B2 at 2180 kg gross weight.**

<b>Temperature</b>	<b>-10°C</b>	<b>+10°C</b>
<b>QNH</b>	1005 hPa	1005 hPa
<b>Hover ceiling</b>	9400 feet P alt (1013 set)	7400 feet P alt (1013 set)
<b>Which gives</b>	9160 feet indicated alt (QNH set)	7160 feet indicated alt (QNH set)

**Effect of reducing atmospheric pressure on OGE hover ceiling example: AS350B2 at 2180 kg gross weight.**

<b>Temperature</b>	<b>+10°C</b>	<b>+10°C</b>
<b>QNH</b>	<b>1030 hPa</b>	<b>995 hPa</b>
<b>Hover ceiling</b>	7400 feet P alt (1013 set)	7400 feet P alt (1013 set)
<b>Which gives</b>	7910 feet indicated alt (QNH set)	6860 feet indicated alt (QNH set)

Remember that, when operating at high density altitudes and weights, the 'four Hs' (**H**igh, **H**ot, **H**eavy, and **H**umid) all combine to reduce helicopter performance.

Ideally the helicopter should be orientated so that the wind is always from its front quarter.



## Wind

### Headwind

Headwind components above translational lift speed encountered while in the hover provide a benefit in terms of improved rotor efficiency and therefore performance.

This effect, however, reduces at wind speeds above the minimum power speed. Headwind is a big advantage because it can mean considerably improved take-off and landing performance, and it can be particularly useful when the helicopter is being operated at the limit of its lifting capability, eg, sling load operations.

Ideally the helicopter should be orientated so that the wind is always from its front quarter. Knowing which direction the wind is coming from is very important – especially in light wind conditions. Some helicopter flight manual performance graphs (eg, Bell 206B3) have a critical wind azimuth area, in which adequate control of the helicopter is not assured when the wind is from anywhere within the specified azimuth area – consequently hover ceiling will be reduced.

Taking off into wind means a lower groundspeed on lift-off, which makes it easier to bring the helicopter to a hover should it become necessary to reject the take-off. Climbing into wind also gives the steepest angle of climb after take-off, which is good for obstacle clearance.

Landing into wind results in a lower groundspeed, which leaves more time to judge the approach. The increase in air flow through the rotor disc means that less power is required to carry out the approach, leaving more power available for the unexpected. A headwind also allows the helicopter to remain in translational lift for longer during the landing approach, meaning a smoother transition and a smaller power increase in the final stages of the approach. Downwind approaches should be avoided where possible because they can result in a vortex ring state, sometimes referred to as power settling.

A difficulty that the helicopter pilot often faces when planning to land at a site where the terrain is significantly affecting the wind speed and direction, is accurately assessing the headwind component.



Tailwind considerations apply here.

### *'Power-pedal-plan'*

Coming into confined areas, make sure you have power in place, pedal in the correct position, with a controlled rate of descent. In the event of an aborted landing and therefore having to fly away, very minimal control input is required.

It's worth considering that when descending below a treeline to land, the assisted wind and increase in temperature below the treeline will degrade aircraft performance.

Make your decision early to fly away and reassess.

If you fail to identify these factors, you'll run out of two things at exactly the same time: horsepower and ideas.

This is particularly so when the landing site is in a valley. Wind speed and direction may

be reasonably constant on the tops, but can be far less predictable down in the valley. The danger is starting an approach based on a particular headwind component, only to have it abate or change direction as the helicopter descends into the valley. Translational lift may be lost, and the power required may increase to a point beyond the power available, resulting in an increased rate of descent and an undershoot. Having a headwind component during the final stages of an approach in this kind of situation should not be taken for granted.

### *Tailwind*

Lifting off with a tailwind means a higher groundspeed and a decreased angle-of-climb, which is bad for obstacle clearance. Tailwind take-offs should be avoided unless absolutely necessary, and then only attempted by experienced pilots.



An important factor, and one that is often overlooked by pilots, is the detection of a tailwind while on approach to land. If the wind speed and direction at the landing site is not obvious, an estimate of whether the groundspeed matches the indicated approach airspeed is good practice. Most helicopters will give the pilot an indication when decelerating through translational lift by the presence of aerodynamic shuddering. Additionally, the observation of higher-than-expected power required for the particular stage of the approach is another clue that a tailwind is present.

Remember – in light wind conditions accurate wind direction assessment can be difficult.

Only a few knots of wind on the tail can make a big difference to the power required to satisfactorily control the rate of descent during an approach – especially when landing at high altitudes.

Landing with a tailwind often results in an early increase in the power required, which may mean that the power available is exceeded. This normally results in an unwelcome rate of descent and an undershoot. Helicopters can be directionally unstable in a tailwind and require anti-torque pedal inputs to maintain the desired direction of travel, which will increase the power required. There is also the possibility of entering a vortex ring state, or power settling. Rates of descent should be kept less than 300 feet per minute during the final stages of the approach (ie, for airspeeds below about 30 knots) to minimise the chances of power settling occurring. If a significant tailwind is detected on approach, an early decision to go-around is usually the best course of action.

Tailwind take-offs and landings should be avoided wherever possible unless there is a very large margin of power available and the pilot is experienced. Maintaining a good awareness of the wind velocity,

power available, airspeed and rate of descent is important at all times during these phases of flight – whatever the wind direction.

### Crosswind

A crosswind situation will affect take-off and landing performance because of the reduced headwind component and the difficulties in maintaining directional control. For example, if the wind is 30 degrees from the take-off or landing heading, the headwind is reduced by 14 percent. If the wind is 45 degrees off, the headwind is reduced by 31 percent. A light crosswind may be either an advantage or disadvantage with respect to take-off and landing performance, depending on whether the wind is from the right or left quarter.

If the helicopter main rotor rotates in an anti-clockwise direction, when viewed from above (American designs), a crosswind from the left side will assist performance. This occurs because the wind effect reduces the thrust required from the tail rotor to counter main rotor torque. The reduced power required then makes more power available to the main rotor for increased lift.

Conversely – using the same helicopter type – if the wind is from the right quarter it will push against the tail boom, vertical stabiliser and the tail rotor disc in the same direction as main rotor torque. This increase in the total rotational force must be overcome by additional tail rotor thrust, thus absorbing more power from the engine. If the engine is unable to produce the additional power required to do this, the pilot must reduce collective pitch, thus causing the helicopter to descend. The pilot must reduce collective pitch to conserve rotor rpm, otherwise the helicopter will rotate and descend in an uncontrolled manner.



### *Turbulence and wind shear*

The possibility of turbulence and wind shear should be considered when determining take-off and landing performance.

Wind shear is a change in wind speed and/or direction over a very short distance. The presence of wind shear can cause the sudden loss of translational lift and increase the power required to that of OGE hover and beyond – particularly if accompanied by a downdraught.

Local terrain, trees and buildings all influence the flow of the wind near them. The mechanical turbulence resulting from this disturbed airflow may become marked in the lee of the obstruction.

In winds below 15 knots, the turbulence in the lee of an obstruction may extend vertically to about one third higher again than the height of the obstruction.

In winds above 20 knots, eddies can occur on the leeward side to a distance of about 10 to 15 times the obstruction height, and up to twice the obstruction height above the ground.

A gusty wind situation where wind shear is likely to be present during take-off will require a greater power margin to deal with any unexpected loss of airspeed and accompanying sink.

Gusty conditions when landing can result in varying power demands and an unstable approach. This may mean the pilot has a problem maintaining a stable rpm range and that the engine is unable to be accelerated (especially a gas turbine) to meet the demand for power. Large anti-torque pedal inputs to maintain directional control also act to reduce the excess power available.

### **Ground effect**

#### *Hover in ground effect*

When hovering at approximately a 3-foot skid height, the velocity of the downwash from the blades reduces because the airflow has to change direction by 90 degrees on contact with the ground.

This change in velocity is felt at the rotor disc in a similar way that the on-coming relative airflow to an aerofoil feels the downwash behind it (ie, induced drag). The result of this interference is to reduce the induced flow through the rotor disc. If the blade angle and rpm are kept the same, the blade angle of attack will increase as the induced flow decreases. This means that lift production increases and the pilot must lower the collective lever to reduce the blade angle of attack and prevent the helicopter from gaining height. Since lowering the collective

means reducing the power required to maintain the same rotor rpm, it follows that less power is required to hover IGE.

Most helicopter flight manuals provide performance graphs to calculate IGE hover ceiling at a skid height of between 2 to 5 feet. Remember that an IGE hover is based on hovering over a flat and relatively smooth surface.

### *Hover out of ground effect*

When hovering above a 3-foot skid height (OGE), the ground resistance is reduced or even eliminated, so there is an increase in the induced flow when compared with an IGE hover. If the blade angle and rpm are kept the same, the angle of attack will decrease as the induced flow increases. This means that lift production reduces, and the pilot must raise the collective lever to increase the blade angle of attack to prevent the helicopter from descending. Since raising the collective means increasing the power required to maintain the same rotor rpm, it follows that more power is required to hover OGE.

This means that OGE hover ceiling will be considerably lower than IGE hover ceiling, as low as 60 percent of IGE.

### *Practical considerations*

When using hover-ceiling charts to determine performance capabilities under a given (known) set of conditions, it's prudent to use conservative values until an element of familiarity is achieved with the operation. To this end, performance calculations should be based only on an IGE hover (ie, a lesser performance margin) when the following criteria are well known to the pilot:

- Familiarity with, and currency on, type
- Accurate assessment of helicopter weight
- Familiarity with the landing zone being used – especially approach and departure routes, obstacles, escape routes, surface, and landing aids
- Ambient conditions at the landing zone especially wind direction and density altitude.

If all the above criteria are not able to be quantified (or a sling load delivery is involved), then the operation must be based on OGE hover performance.

**Caution:** Don't forget there will be situations where further calculations may be required to effect a safe departure from some pads that, for instance, require a towering climb from a confined area.



Uneven terrain offers only partial benefits of ground effect



More power is required to hover over a sloping surface.

Photo: istockphoto.com/simonbradfield

## Slope

Hovering above sloping ground will require more power than that needed to hover over a flat surface. Hovering over a slope allows some of the downwash on the downhill side to escape. This means that the induced flow through the rotor disc is not as greatly affected, resulting in a loss of the benefits that would permit an IGE hover. More power is therefore required to hover over a sloping surface. In such situations, prudent pilots will base their performance calculations on an OGE hover.

An up-slope wind when hovering above a slope has the advantage of requiring less into-slope cyclic to hold the helicopter level. This means that more cyclic movement is available to the pilot to control the helicopter. Strong up-slope winds can reduce tail rotor authority and, if anti-torque pedal inputs are made, increase the power required.

## Surface

Any surface that absorbs the downwash from the rotor blades will reduce the benefits of ground effect. Hovering over long grass, rough water, rocky river beds, a tree canopy, or similar surfaces, requires more power and will thus reduce the IGE hover ceiling.

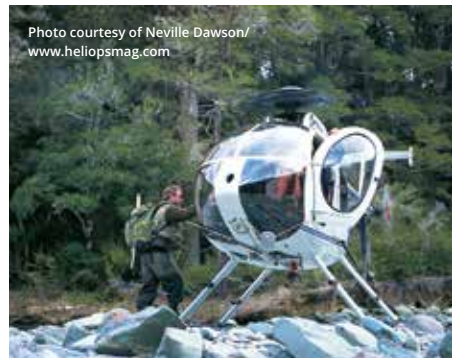


Photo courtesy of Neville Dawson/  
www.heliopsmag.com



# Other considerations

## Power checks

Conditions at take-off and landing sites are likely to differ from what has been allowed for during flight manual performance calculations. In order to take this into account (plus the fact that flight manual performance graphs tend to be optimistic), and to confirm the amount of excess power available, the pilot must make an operational assessment by doing a power check before committing to a take-off or a landing.

### Before take-off

Determining the excess power available at take-off not only gives the pilot a good idea of whether obstacle clearance will be adequate, but also what the climb performance is likely to be (valuable information when operating at high density altitudes), and whether or not a landing at an even higher elevation will be feasible. Checking the excess power available prior to take-off is a useful tool to indicate a departure from 'expected' performance values. See the section on power assurance checks on page 23.

The excess power in hand for take-off can be determined as follows:

- Hover IGE and note the minimum power required to do so.
- Check the maximum power available for the given ambient conditions by slowly\* starting a vertical take-off until maximum collective input is achieved; note the corresponding MAP or torque. Sometimes the pilot may already have a good idea of this value from a power check prior to landing at the site.

*\* Taking off slowly prevents the possibility of entering a vortex ring state, should less power than expected be available and the helicopter sinks unexpectedly.*

- Be sure to make an allowance for a reduction in the power required to hover if there's a significant headwind, otherwise the value obtained may be misleading.
- Compare the two values. The difference represents the power margin available and indicates the type of take-off that will be possible, ie, running, cushion-creep, towering, or vertical.
- The prevailing wind, terrain, escape routes at the site will then dictate what type of take-off profile needs to be made.

Before take-off, assess power available.





If the power available for take-off is marginal, the cushion-creep method should be used. This requires the pilot to:

- turn the helicopter into wind.
- hold the maximum allowable rotor rpm.
- raise the collective lever until the skids clear the surface, then use a small amount of forward cyclic to initiate forward momentum.
- keep the skids as close as practical to the ground to fully utilise ground effect until translational lift is achieved.
- accelerate to best-rate-of-climb speed and establish a satisfactory climb.

The main objectives of this technique are to keep the total rotor thrust almost vertical and to utilise ground effect as much as possible.

Should the power required for take-off be more than the engine is capable of delivering, a reduction in rotor rpm will occur. With a reduction in rotor rpm, the pilot will be tempted to increase the collective pitch to avoid the helicopter settling back on

to the ground. Increasing rotor blade angle of attack, however, increases drag, further reducing rotor rpm. With any decrease in rotor rpm, there will be a reduction in the effective disc area because of an increase in the coning angle. This extreme situation may not be recoverable, and is referred to as overpitching.

In the event a pilot overpitches the rotors, only one recovery method is available and that is to reduce the blade pitch angle by lowering the collective with the throttle set at maximum. Overpitching is discussed on page 24.

Refer to your helicopter flight manual or consult an instructor or senior pilot for specific details on doing a power check prior to take-off.

### *Before landing*

Many landings are preceded by a hover, and since power required to hover is greater than that required for forward flight, it follows that special care is needed for landings at high gross weights in high density altitudes. Keeping the wind on the nose is essential in such circumstances.

The method for assessing the power in hand before landing is based on similar principles to that used for the take-off, except that it is normally done in forward flight and at an altitude similar to the landing site. A power check is usually accomplished as follows:

- Fly straight and level at a pre-determined speed (usually minimum-power speed) with landing rotor rpm selected, taking care to avoid air that is subject to up or downdraughts.
- Note the MAP or torque.
- While maintaining the same rotor rpm, briefly apply full power and note the corresponding change in MAP or torque. Note that it's usually not practical or necessary to maintain the same airspeed at this point.
- The difference between the two values gives a clear indication of the type of approach and landing that can be safely carried out at the site.

Any headwind component will obviously be an advantage here, but it should not be relied on, as it may abate just when you need it most. Using the R22 as an example, six inches of excess MAP should enable an approach to be made to an OGE hover, whereas just three inches of excess MAP will usually mean that only a run-on landing will be possible – but this is not recommended. Refer to the flight manual for specifics.

An alternative method is to check the power required to hover OGE adjacent to the landing site, and compare it with the power available. This must be done with a pre-determined escape route in mind over a clear area with plenty of height to spare, because the power required to hover OGE at high density altitudes can be large. The helicopter can quickly develop a high rate of descent if there is insufficient power available, so be alert and avoid entering a vortex ring state.

### Power assurance checks

Because engine performance can deteriorate between overhauls, regular power assurance checks must be done to confirm that engine output is within the manufacturer's specifications. 'Below spec' engines cannot be relied on to meet flight manual performance graph figures. Ensuring that engine instruments are accurately calibrated is also an important part of the power assurance process. Incorrect readings are dangerous and can mislead a pilot into thinking there is more power available than there really is.

The results of a power assurance check should be recorded and a baseline established for the engine concerned. Subsequent power checks will then indicate any degradation in engine performance and can be allowed for accordingly.

### Decision points

A decision point should always be nominated where the take-off will be rejected, the load jettisoned, or the landing approach discontinued, if things are not going as expected.

For take-off, this is the point at which either there is sufficient distance and height remaining to safely bring the helicopter to a hover, or to accelerate it to a safe flying speed down a pre-determined escape route (eg, in a ridge-top situation where height can be sacrificed) should the helicopter climb more slowly than expected, or have a power loss. This is particularly important for multi-engine helicopters. Plan to clear obstacles in the climb-out path by at least 50 feet.

For an external load operation, have a pre-determined point where the load will be jettisoned should the helicopter not achieve adequate climb performance after lift-off. Also, have a good idea where to put the load if the helicopter develops a higher-than-expected rate of descent (sink) on



approach to land. Things can happen quickly, so the less time spent thinking about where to put the load the better – a pre-determined plan can make all the difference. For landing, the decision point should be the height at which there is sufficient room to safely discontinue the approach while there is translational lift, should you not be satisfied with the approach and confident that the helicopter can be brought safely to a hover. As for take-offs from challenging ridge-top sites, where possible, you should have a suitable down-slope escape route in mind before committing to the landing.

### Speed control

Accurate speed control after take-off is important when, for obstacle clearance, you need to achieve the best angle-of-climb performance from your helicopter.

For landing, accurate speed control is important so that a stabilised approach can be flown. This is particularly important when the transition from translational lift to ground effect is made – especially when making a zero-speed landing. If you get too slow too early, the helicopter may develop a high rate of descent. Get too fast, and large or rapid control inputs may be required to overcome the helicopter inertia, where 'power settling'\* may occur.

\* Not to be confused with 'settling with power' (vortex ring).

### Overpitching

Overpitching is a dangerous situation; the engine can no longer provide enough power to overcome the drag of the main rotor at high collective pitch settings. The result is a reduction in rotor rpm, thrust, and centrifugal force, which in turn reduces the effective lifting area of the rotor disc. The pilot must react quickly to correct the situation and prevent a dangerous rate of descent from developing. Remember, if you are close to the ground, there may be insufficient height to recover. Techniques to recover from an overpitched state should be discussed with an instructor or senior pilot.

A situation that leads a pilot to inadvertently overpitch the rotors usually means the pilot has not determined whether or not the proposed operation was within the helicopter performance envelope. The pilot may also not have done an adequate power check at the operating site prior to committing themselves. Remember, gross mishandling can also bring about overpitching, even if adequate power is available.

Overpitching can be prevented if the pilot plans ahead, does the necessary performance graph calculations, and validates them with a power check at the operating site.



A quick stop: never downwind.

## Pilot technique

Getting the best performance out of your helicopter relies on using the correct flight manual techniques and being current enough to apply them accurately. For instance, you must ensure that the recommended maximum performance take-off technique is always used when operating out of a confined area, which includes flying the climb-out at best-angle-of-climb speed for optimum obstacle clearance. Likewise, knowing what kind of landing technique to use in a particular situation, and being able to fly it accurately, is just as important.

Consult the flight manual, or an instructor, if you are unsure what take-off or landing technique to use, where performance is a consideration. Get some dual revision if you are rusty or not current.

## Vortex ring state

Vortex ring state is a serious hazard all helicopter pilots need to be aware of.

Vortex ring state occurs when a recirculation vortex envelops a helicopter's rotor system, causing significant loss of lift.

This can occur when the helicopter is descending at a reduced airspeed, and is most at risk of happening during downwind approaches. The likelihood

of vortex ring state is increased with a helicopter at a heavier weight due to a higher power setting requirement.

The condition can be sudden, and it results in a rapid increase in rate of descent. Any increase in rotor thrust to reduce this further energises the vortices and increases the rate of descent.

The standard vortex ring state recovery technique requires pilots to reduce power by lowering the collective and accelerating forward away from the downwash. However in the low level environment this may not always be possible as it consumes valuable height.

Alternatively, the Vuichard Recovery technique can be used to move out of the vortex ring. This involves increasing collective to climb power, applying the appropriate pedal (generally left in American helicopters, and right in European helicopters) to keep the nose straight, and applying the appropriate cyclic (opposite to the pedal used).

Of course, avoiding vortex ring state is the best course of action. This requires pilots to:

- Remain alert to the conditions conducive to the formation of vortex ring state.
- Closely monitor the airspeed and rate of descent during the final approach.
- Initiate recovery action at the first indication that they may be approaching vortex ring state.





## Rotor condition

Deposits on the main or tail rotor blades can disrupt the laminar airflow and significantly reduce the lift production. For example, a frost coating can grossly disrupt the laminar airflow. Other such deposits could include spray residue, insects, dust, dirt, and pollen. Nicks and dents, or ripped and rough leading edge blade tape, can also disrupt the laminar airflow.

Keep all rotor surfaces damage-free and clean to ensure maximum performance, because you never know when you might need that extra bit of performance. Any downtime spent cleaning and inspecting rotor blades is time well spent.

## Contingencies

Even after having worked out your helicopter take-off, landing or lifting performance, it is prudent to add a contingency to allow for other factors that you may have overlooked. For instance, the engine may not be performing as well as it used to, the rotors may be less efficient than they used to be,

you might encounter an unexpected lull or shift in the wind, the air temperature at the landing site might be higher than anticipated because of surface heating, you might not be as current as you think you are, and so on. Remember, many flight manual performance graphs are somewhat optimistic and are based on test data from a brand-new helicopter being flown by an experienced test pilot – all the more reason to add a contingency.

When the performance figures are looking tight, always factor a contingency of at least 10 per cent into your calculations.

## Know your helicopter

The importance of being thoroughly familiar with your helicopter's performance capabilities cannot be overstressed. Time spent reading the performance section of the flight manual, and talking to another pilot who has experience of that helicopter type, is time well spent. Even then, it's prudent to adopt a conservative approach to operations where performance is a consideration, until you feel really comfortable with the helicopter.

# Determining performance

The following section contains worked performance examples, plus further examples for you to test yourself on.

## Examples

### *Take-off performance example*

Let's work through a take-off performance example using the H269C IGE hover ceiling chart provided in Figure 3. The red line relates to the data supplied below, and the blue line provides a comparison for 'standard' conditions.

You are the pilot of a H269C who needs to calculate the IGE hover ceiling of your helicopter to determine if you can safely pick up some deer shooters from an elevated ridge-top site under the following conditions. You have just called them on their cellphone to find out what their combined weights (which includes gear) are. Can you safely accept the job?



<b>Gross weight</b>	930 kg (assume full fuel tanks)
<b>Temperature</b>	+25°C at sea level
<b>QNH</b>	1003 hPa
<b>Wind</b>	Nil
<b>Take-off site elevation</b>	5300 feet amsl (there are no obstacles of note on the climb-out)
<b>Surface</b>	flat short grass

### Workings

**Step 1.** The first thing we need to do is to calculate the site **pressure altitude**. To do this we need to take the elevation of the landing site and correct it for atmospheric pressure.

Knowing that 1013.2 hPa is ISA pressure at sea level, we calculate the difference from today's QNH (sea level pressure), which is 1003 hPa. The difference is 10 hPa, and as each hectopascal equals approximately 30 feet, this equates to 300 feet. We must now apply this correcting figure to our take-off site elevation of 5300 feet. Do we add it or subtract it?

Because the pressure is lower than standard (pressure decreases with altitude, 1003 hPa being found at 300 feet amsl on a standard day) we add the figure to take-off site elevation, arriving at a pressure altitude of 5600 feet.

**Step 2.** Now that we have determined the pressure altitude, we must calculate what is effectively the density altitude (not actually represented as a numerical value on the graph). Our sea level temperature in this case is 25°C, ie, 10 degrees higher than ISA's 15°C at sea level, and so we describe the conditions as ISA+10°C.

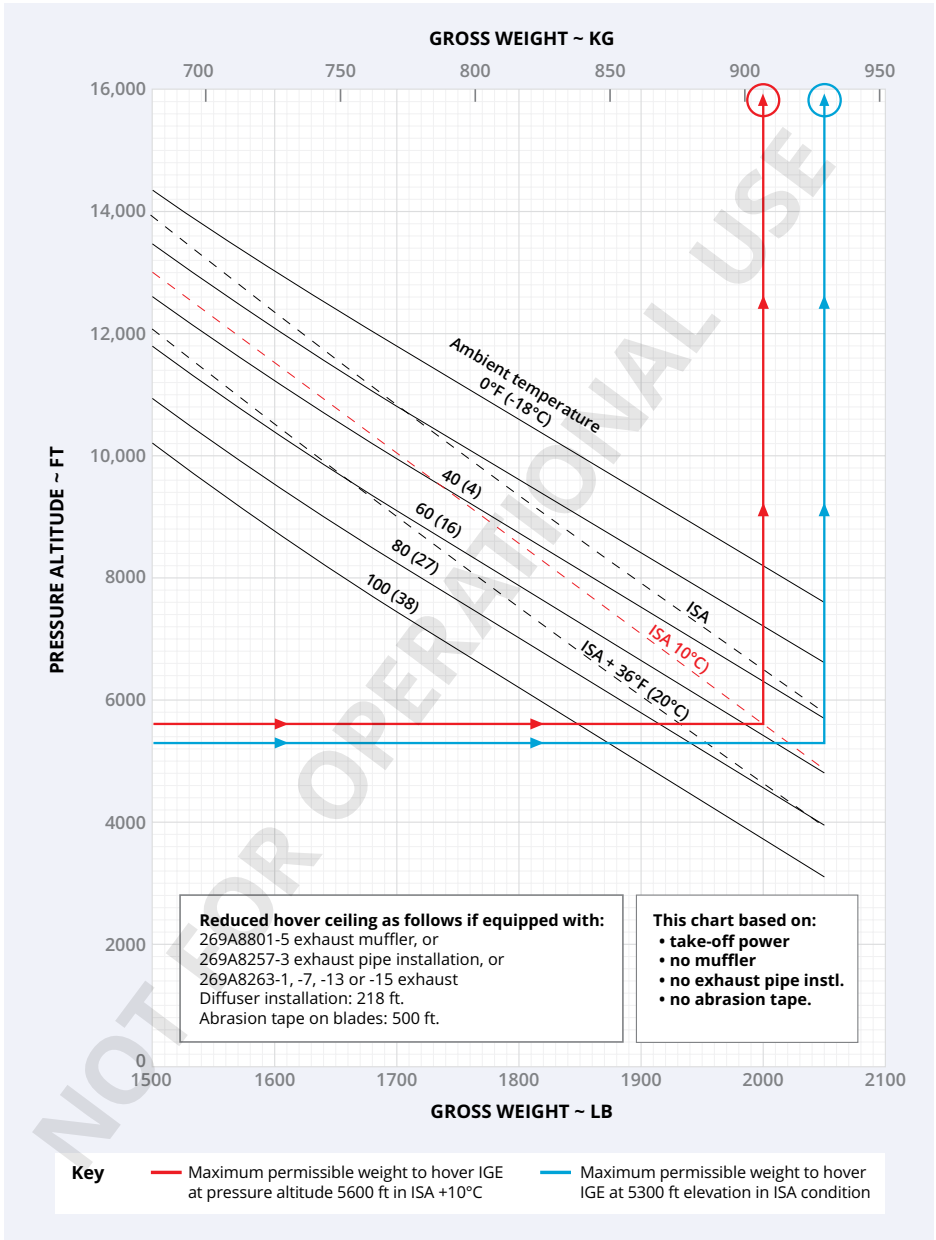
**Note:** For an approximation of the theoretical temperature at a pressure altitude of 5600 feet, extrapolate the sea level temperature at 2°C cooler per 1000 feet. Thus, 2 times 5.6 equals 11° colder than the 25° sea level temperature, giving a theoretical 14°C at 5600 feet.

Surface heating may, however, cause the air temperature immediately above the landing site to be higher than any derived or calculated value, which would mean an increase in the local density altitude. You may wish to make an allowance for this when entering the temperature.

Carefully draw a line that represents the ISA+10°C temperature profile parallel to the existing ISA reference line and use that as your reference datum, being careful not to confuse °F with °C. Note that some manufacturers do not provide this ISA line so you will have to draw your own by plotting several points using the known ISA pressure altitude and temperature relationship.

**Figure 3**

SCHWEIZER 269C helicopter IGE hover (3200 rpm) ceiling graph (takeoff performance example)



**Note:** If we had a reading of what the actual air temperature was at the take-off site, we would draw a line parallel to the appropriate ambient temperature line rather than the ISA line.

We can now enter the vertical axis of the graph at 5600 feet pressure altitude and track horizontally across to the ISA+10°C temperature line that we have just drawn. The intersection of these lines indicates the density altitude at the site.

**Step 3.** Finally, the graph is exited by tracking vertically upwards to the horizontal axis to determine what the maximum weight is for that density altitude.

In this case, the theoretical gross weight that your helicopter could hover IGE at such a density altitude is 910 kg. Since you calculated that the shooters' combined weight plus full fuel would bring the helicopter gross weight up to 930 kg, you would be 20 kg overweight.

At the lighter weight of 910 kg you should, in theory, be able to hover IGE at the take-off site under these conditions, but you would have little excess power available to take-off. However, if you off-loaded some fuel (assuming no adverse effect on safe endurance) or make two trips you would be considerably lighter. You could reasonably conclude that you could take-off safely at this new weight, but this would need to be validated with a power check prior to taking off at the site. This would tell you what kind of take-off you could achieve and what sort of climb performance to expect – something that is important when operating in mountainous terrain.

### *Landing performance example*

Now work through the following landing performance example, using the Bell 206B3 OGE hover ceiling chart provided in Figure 4. Again, the red line relates to the data supplied below and the blue line provides a comparison for 'standard' conditions.

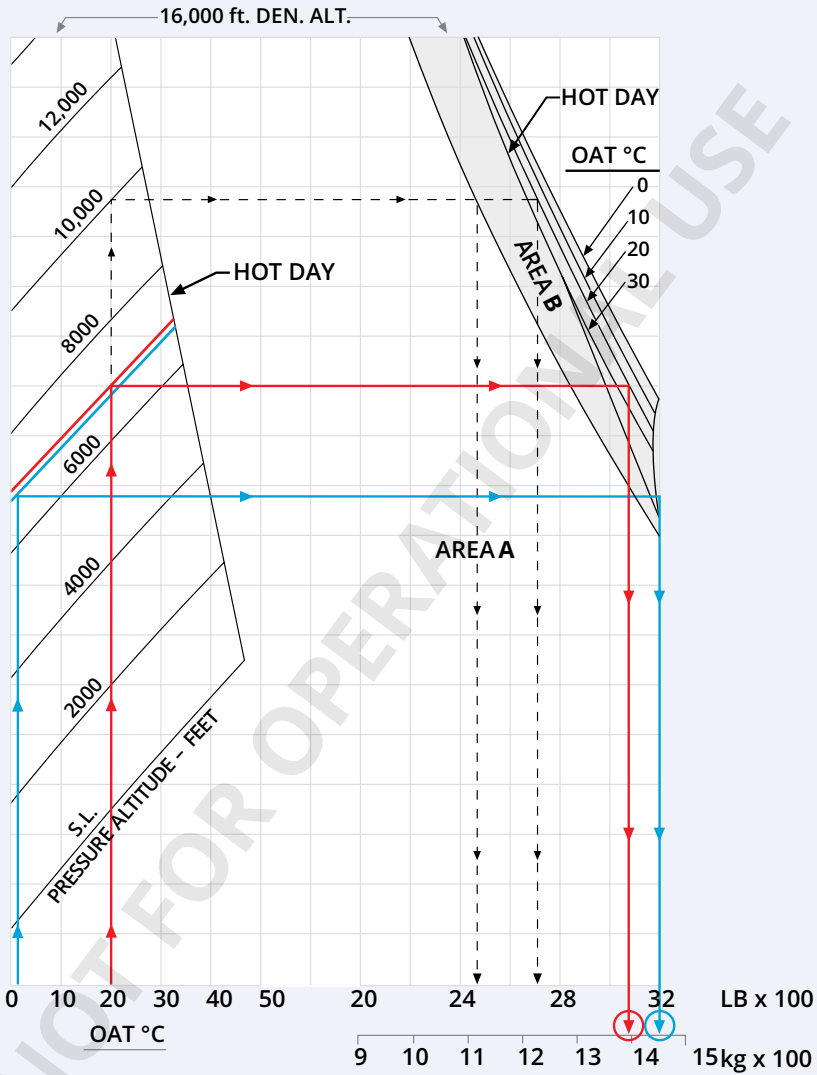
Let's say you're the operator of a Bell 206B3, and a broadcasting company has asked you to lift a heavy radio repeater onto a ridge-top site in Mt Cook National Park. The repeater cannot fit inside the helicopter so a sling load operation will be necessary. The landing site is flat on fine scree and is clear of obstacles on the approach. Can you safely accept the job?

The season is mid-summer, so you decide to base your calculations on a hot day, with low pressure and no headwind component at the site just to be safe. Since the operation involves a sling load, the calculations will need to be based on an OGE hover.



**Figure 4**

Bell 206B3 OGE hover ceiling graph (landing performance example)



- Key**
- Maximum permissible weight to hover OGE with 20°C and pressure altitude of 6,940 ft at site
  - Maximum permissible weight to hover OGE with ISA at pressure altitude 6,700 ft

<b>Gross weight</b>	1455 kg (assume full fuel tanks)
<b>Site air temperature</b>	+20°C
<b>QNH</b>	1005 hPa
<b>Wind</b>	Nil
<b>Landing site elevation</b>	6700 feet amsl
<b>Surface</b>	flat, fine scree

### Workings

**Step 1.** The first thing to do is to calculate the site **pressure altitude** using the method described in the previous example. In this case pressure altitude is 6,940 feet (6700 ft + 240 ft). A line representing this value is drawn parallel to, and the appropriate distance below, the 7000-foot pressure altitude reference slope at the left of the graph.

**Step 2.** Next, determine the site **density altitude**. The site temperature is estimated at 20°C using the standard temperature lapse rate. A line is then drawn vertically up from 20°C mark on the graduated temperature scale at the bottom left of the graph to intercept the 6940-foot pressure altitude reference line that has been drawn. The intersection of these lines indicates the density altitude at the site.

A line is drawn horizontally across from this point until it intersects the 20°C sloping performance-limit line inside shaded Area B at the top right of the graph. Area B relates only to operations in calm wind conditions, or wind directions that will be outside the helicopter's critical wind azimuth area. The absence of wind in this situation would satisfy this requirement. Note that the B206B3 is not performance-limited for density altitudes below approximately 4000 feet.

**Step 3.** Finally, the graph is exited by drawing a line vertically downwards from this point to the horizontal weight axis, where the maximum permissible OGE hover weight is read.

The maximum weight the helicopter can hover OGE at this density altitude is 1390 kg. Therefore, it will not be possible to safely do the job at 1455 kg. Off-loading 80 litres of fuel would bring the helicopter weight down to approximately 1390 kg, where it would be reasonable to conclude that the job could safely be carried out under the specified conditions. (This figure would need to be validated by a power check near the site.) Alternatively, you may decide to wait for a cooler day with a higher pressure, or a steady headwind, to do the job.



## Conclusion

Take-off, landing and hovering are all potentially risky phases of helicopter flight. The more that we can do as pilots to minimise these risks – especially when operating at high gross weights, from challenging sites, with high density altitudes – the safer we will be.

Most performance-related accidents can be prevented, provided that the pilot maintains a good awareness of the surrounding conditions, knows the performance limitations of the helicopter, always does a power check before committing to a marginal situation, and is disciplined enough to 'give it away early' if the odds are stacking up against getting the job done safely.

Before each confine or remote landing, carry out a power check to ensure you have appropriate horsepower – remembering that flight manual performance data can be optimistic.

// Always make performance calculations part of your flight preparation. //

## Performance questions

Now that you have had a brief refresher using hover ceiling graphs, try these problems by using the graphs provided (answers on page 35):

### 1. Calculate the IGE hover ceiling, given the following:

Type	Schweizer 269C
Gross weight	900 kg
Temperature	+20°C at sea level
QNH	1013 hPa

### 2. A farmer asks you to sling-load some fencing equipment onto a high ridge-top site. Is the job within your helicopter performance capabilities, given the following?

Type	Bell 206B3
Gross weight	1430 kg
Temperature	+20°C at ridge-top site
QNH	1003 hPa
Site elevation	4300 feet amsl

### 3. What is the maximum weight I can hover IGE at an elevation of 6200 feet, given the following?

Type	Schweizer 269C
Temperature	+25°C at sea level
QNH	1025 hPa
Elevation	6200 feet amsl

### 4. A friend asks if you can fly four college students and their packs into a tramping hut in the Taranaki Ranges. You say that you'll do some calculations and let them know if it's feasible.

What would your answer be given the following?

Type	Bell 206B3
Helicopter empty weight	800 kg
Pilot and pax weight	400 kg
Fuel weight	160 kg
Combined pack weight	90 kg (sling load)
Temperature	+25°C at site
QNH	1003 hPa
Site elevation	5800 feet amsl



#### Answers to performance questions:

1. IGE hover ceiling would be 6200 feet pressure altitude.
2. Yes, you could accept the job. An OGE hover will be possible at 1430 kg.
3. Maximum weight to hover IGE is 890 kg.
4. The answer is no, you would only be able to hover OGE at 1400 kg maximum. You would need to off-load at least 50 kg before undertaking the flight.



---



**Good Aviation Practice**

---



PO Box 3555  
Wellington 6140

Tel: +64 4 560 9400  
Fax: +64 4 569 2024

Email: [info@caa.govt.nz](mailto:info@caa.govt.nz)

New Zealand Government

See the CAA website for Civil Aviation Rules, advisory circulars, airworthiness directives, forms, and more safety publications.

To request publications such as GAPs and posters email: [publications@caa.govt.nz](mailto:publications@caa.govt.nz).

**[aviation.govt.nz](http://aviation.govt.nz)**

*Helicopter performance*  
was revised in February 2020.