

# *Helicopter Performance*

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Photo Neville Dawson

**Performance-related helicopter accidents continue to occur frequently in New Zealand – more than 45 cases since 1991. Most accidents happen in the takeoff and landing phases of flight. They usually involve a failure by the pilot to adequately determine that the power required for the intended manoeuvre is available given the prevailing conditions. This booklet examines the factors affecting performance and provides guidance to help pilots ensure a proposed operation can be accomplished safely.**

## **Acknowledgements**

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

This booklet is dedicated to the memory of the late Brian O'Hagan, accomplished instructor and helicopter pilot, whose technical advice was invaluable.



Over the last ten years around 20 percent of all New Zealand helicopter accidents have been performance-related. Approximately 60 percent of these accidents occurred during the takeoff or landing phases of flight, the remainder being associated with an external load or confined-area operations. Many of these accidents happened when the helicopter was being operated from sites that were elevated, facing out of wind, restricted by terrain, sloping, or had a rough surface. In most cases the sites were on ridge tops or in confined, steep-sided valleys. Often the helicopter was being operated at a high gross weight, in high temperatures and low air pressures.

Many, if not all, of these accidents could have been avoided if the pilots had been fully aware of the prevailing conditions and taken the time to determine the performance capabilities of their machine 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 verified with an actual power check under the ambient conditions that exist 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 have used piston-engine examples here, turbine-powered helicopters are also susceptible to performance problems.)

## Too High

A helicopter operator was approached by a trapper who wished to be flown to a hut in the mountains, apparently at an altitude of 1,450 feet amsl. The pilot assigned to the job flew the Robinson R22B to the airport where the trapper waited.

The pilot assessed the weight of the trapper, pack, aircraft, and fuel and considered them to be within the aircraft's capability to operate at the elevation of the hut. Some items from the trapper's pack were stowed under the seat, and the pack was placed at his feet. A hover check in ground effect (IGE) was made – showing 24 inches manifold air pressure (MAP) to be necessary.

The trapper guided the pilot to the hut, which turned out to be at a much greater height than expected. The pilot carried out a power check and decided to land on a nearby tussock-covered saddle. This was approached obliquely to allow for an escape route, and the aircraft was flown at 22 inches MAP in a shallow approach.

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 now inevitable, the pilot tried to control the flight path by increasing collective pitch. The forward motion could not be arrested fully using full aft cyclic, and the aircraft began to rotate, touching down heavily. It then pitched slowly onto its nose and fell on to its right side.

## Analysis

Overall, this flight had the odds stacked against it being carried out successfully, although there were 'outs' along the way.

The pilot had been misled by the trapper as to the elevation of the landing site. The trapper was using the new NZMS 260 series of maps, which show heights in metres. The altitude of the hut was 1,450 metres amsl (4,750 feet), not 1,450 feet as reported by the trapper.

Another significant factor was the aircraft weight and balance. Using the weights estimated by the pilot, the weight at takeoff was 635 kilograms, 13 kilograms over the maximum. This inevitably placed a premium on the power required. Moreover, by placing the pack at the trapper's feet, the aircraft was probably loaded outside the forward C of G limits. This would have added to the difficulties of using cyclic to stop forward motion.

Lack of a power margin was inevitable given the helicopter's weight and the density altitude at the landing site, but the pilot failed to recognise the shortfall in power. The pilot carried out a power check estimate as he approached the landing area, but failed to apply the technique fully; that would have revealed that the power



required was 24 inches MAP and the power available was 23 inches. A no-go situation would then have been evident.

Having recognised that there was insufficient power available, the pilot used the incorrect recovery technique. At 15 feet above the landing site, the helicopter could possibly have been accelerated to 15 knots to gain translational lift, the power requirement would then have been reduced significantly, and the pilot could have taken time out to figure out other ways of delivering the trumper and his pack.

### **Insufficient Power**

The purpose of the Robinson R22B helicopter flight was to land the passenger by the south side of a small lake at 5,300 feet 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. The lake surface indicated no wind.

On short final the pilot found that the helicopter did not slow as intended, and on losing translational lift, the rotor rpm started to decay, while not fully arresting the sink.

The helicopter was turned away from the knoll toward lower but uneven ground in an effort to make a controlled landing. The landing was heavy enough to cause the left skid to collapse and the helicopter to roll over.

Full carburettor heat had been applied when



power was reduced for the approach, but it had not been returned to the COLD position before landing. A subsequent flight check in the area indicated that this reduced maximum manifold pressure 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 5,300 ft amsl with the two persons and hook load on board, but it seems from events that the margins were small. The loss of manifold pressure from having carburettor heat selected, together with a possible light tailwind, presumably tipped the balance.

The situation would have deteriorated fairly rapidly, but jettisoning the load on the hook might have restored the balance enough to avoid the accident.

## PIC Responsibilities

Section 13 of the Civil Aviation Act 1990 clearly indicates that it is the responsibility of the pilot in command to ensure that they operate their aircraft in a safe manner with respect to performance. More specifically, Civil Aviation 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’s Flight Manual. Enter the graph and trace the applicable data to determine the performance capabilities for the given conditions – and

then confirm those values through the application of a power check. Most Flight Manuals have graphs for determining density altitude, IGE and OGE hover ceilings, takeoff distances, and rate-of-climb performance. Note, however, 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.

## 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, as there are differences between helicopter types – the application of rules-of-thumb could be potentially 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. Please refer to your helicopter Flight Manual or

operating procedures, or ask your chief pilot/instructor for the specific performance information that applies to your machine.

It should be noted that the performance values derived for the following examples may be **significantly better** than what the

helicopter can **actually** achieve in reality. They are based on a brand new machine (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 somewhat optimistic. It should also be borne in mind that engine performance can deteriorate between overhaul periods. All examples have been



derived from Flight Manual performance graphs only, and they would normally be verified with an actual power check under the ambient conditions that exist 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). It is important that the correct variant is used so that accurate performance data is obtained.

## Weight

It can be easily seen that the greater the gross weight of the helicopter the more lift (rotor thrust) will be required to hover or

climb. The amount of lift available is proportional to the collective setting and its associated angle of attack. The power available determines the maximum collective pitch setting that can be maintained at the optimum rotor rpm. Therefore, 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 two examples given below.

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

Gross weight:	<b>725 kg</b>	<b>910 kg</b>
Temperature:	+27°C @ sea level	+27°C @ sea level
QNH:	1003 hPa	1003 hPa
Hover ceiling:	11,350 feet P alt (1013 hPa set)	5,400 feet P alt (1013 hPa set)
Which gives:	11,050 feet indicated alt (QNH set)	5,100 feet indicated alt (QNH set)

It is important that the pilot has some method of determining what the gross weight of the helicopter is prior to flight. This means totalising the weights of the crew, passengers, fuel and any other items being carried in a systematic way that will allow accurate performance calculations to be carried out should they be required. 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 altitude, because the air near the earth's

surface is compressed by the air above it. As altitude increases pressure reduces. Air is free to expand and therefore becomes less dense.

### *Effect of Temperature on Density*

Temperature generally decreases with altitude. This causes the air to contract and become more dense. However, the drop in pressure as altitude is increased has the dominating effect on density when compared with the effect of 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. It is important that a sense of moisture assessment is developed and the expectations of the helicopter's perfor-

mance adjusted accordingly. Essentially, hot and humid conditions usually mean poor engine performance and reduced lift production – factors that should never be underestimated when operating at high density altitudes and gross weights.

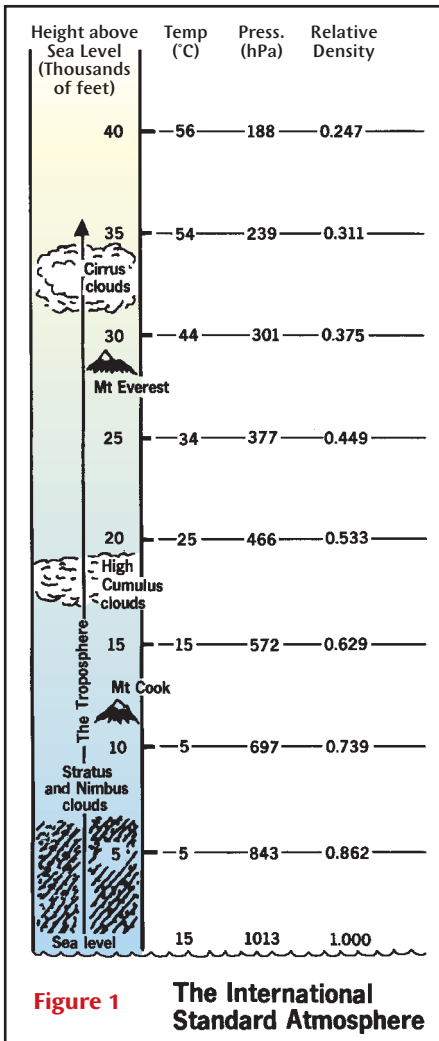


Photo Neville Dawson



## 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.

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 any altitude in the atmosphere is greater than the temperature would be in the standard atmosphere at the same altitude, then the air at that altitude will be less dense than in the standard atmosphere.

## Density Altitude

*Density altitude* represents the combined effect of pressure altitude and temperature. It 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,

however, something that we normally have to do as pilots in practice, as the temperature reference lines on a performance graph work this out for us). But it is still useful to know what is being calculated. More on that later.

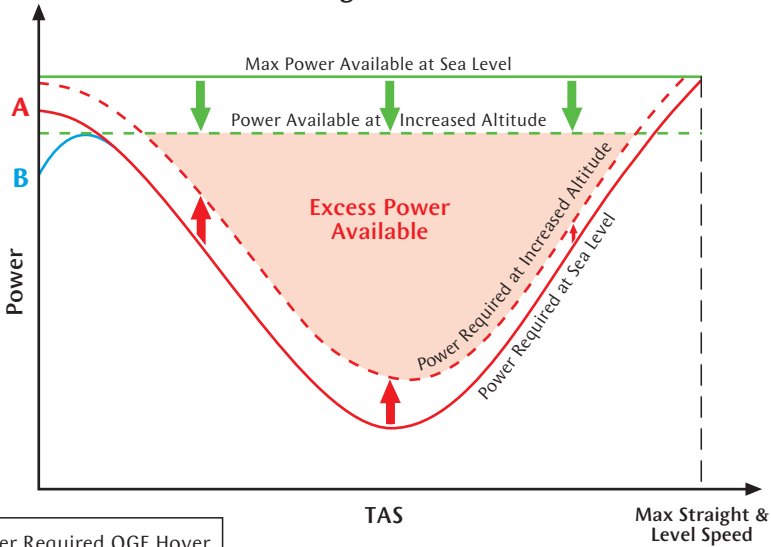
Helicopter performance is highly dependant on air density, which directly affects engine power, drag, and rotor efficiency. As air density decreases, performance decreases. Density altitude, therefore, provides a basis for relating air density to ISA, so that comparative helicopter performance can be readily determined. High density altitudes are usually found at high-elevation takeoff/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 sites in these conditions can be fraught with danger – your performance sums have got to be right.

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 turbine engine also falls off at a similar rate as density altitude increases. It may ultimately become total temperature or gas producer limited, which will limit the power available.

Because the margin between the power available and the power required to sustain hover flight at high gross weights and

**Figure 2** Effect of Increasing Altitude on HPA/HPR



**A** = Power Required OGE Hover  
**B** = Power Required IGE Hover

high density altitudes is often small for helicopters, density altitude becomes important to the helicopter pilot; more so than it is 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 – which often means the choice of takeoff and landing sites available to the pilot becomes more limited.
- Reduced operating margins – means reduced payloads.
- Reduced rate-of-climb performance – means obstacle clearance can be adversely affected.

### **Takeoff**

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



available, or the surface may be unsuitable. This is the reason why the power required for the type of takeoff to be performed and the power available to achieve it must **always** be carefully assessed beforehand. This is discussed further later in this booklet.

Translational lift must be achieved as soon as possible after liftoff and the helicopter accelerated to the speed for best climb angle. If not specified in the Flight Manual, this approximates to translational speed plus 20 knots (which is also known as best endurance 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. Methods of achieving a

landing under such conditions may be to make 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 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 by conducting a power check. (Conducting a power check is covered later in this booklet.)

### Some Examples

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



#### Effect of increasing temperature on OGE hover ceiling example: R22B

Gross weight:	590 kg	590 kg
Temperature:	<b>ISA -10°C</b>	<b>ISA+10°C</b>
QNH:	1005 hPa	1005 hPa
Hover ceiling:	7,100 feet P alt (1013 set)	5,900 feet P alt (1013 set)
Which gives:	6,860 feet indicated alt (QNH set)	5,660 feet indicated alt (QNH set)

#### Effect of reducing atmospheric pressure on OGE hover ceiling example: R22B

Gross weight:	590 kg	590 kg
Temperature:	ISA+10°C	ISA+10°C
QNH:	<b>1030 hPa</b>	<b>995 hPa</b>
Hover ceiling:	5,900 feet P alt (1013 set)	5,900 feet P alt (1013 set)
Which gives:	6,410 feet indicated alt (QNH set)	5,360 feet indicated alt (QNH set)

### Effect of increasing temperature on OGE hover ceiling example: AS350B2

Gross weight:	2180 kg	2180 kg
Temperature:	<b>-10°C</b>	<b>+10°C</b>
QNH:	1005 hPa	1005 hPa
Hover ceiling:	9,400 feet P alt (1013 set)	7,400 feet P alt (1013 set)
Which gives:	9,160 feet indicated alt (QNH set)	7,160 feet indicated alt (QNH set)

### Effect of reducing atmospheric pressure on OGE hover ceiling example: AS350B2

Gross weight:	2180 kg	2180 kg
Temperature:	+10°C	+10°C
QNH:	<b>1030 hPa</b>	<b>995 hPa</b>
Hover ceiling:	7,400 feet P alt (1013 set)	7,400 feet P alt (1013 set)
Which gives:	7,910 feet indicated alt (QNH set)	6,860 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 produce a significant reduction in helicopter performance.

## 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 approaching the speed for minimum total drag. Headwind is a big advantage, as it can mean considerably improved takeoff and landing performance, and it can be particularly useful where the helicopter is being operated at the limits of its lifting capability, eg, sling-loading operations.

Ideally the helicopter should be orientated so that the wind is from its front quarter at all times. Knowing which direction the wind is coming from is, therefore, absolutely



critical – 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 – hover ceiling will be reduced as a consequence.

Taking off into wind means a lower groundspeed on liftoff, which makes it easier to bring the helicopter to a hover should it become necessary to abandon the takeoff. Climbing into wind also gives the steepest angle of climb after takeoff, 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 perform the approach, leaving more power available for the unexpected. A reasonable 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 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. 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 commencing 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. A headwind component during the final stages of an approach in this kind of situation should not be relied upon.

### *Tailwind*

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

Light wind conditions are probably some of the most critical conditions for getting the wind direction right.

Just a couple of knots of wind on the tail can make a huge 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 are also directionally unstable in a tailwind and require pedal inputs to maintain the desired direction of travel – this will increase the power required if the anti-torque pedal is used. There is also the possibility of encountering vortex ring state/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 this phenomenon occurring. If a significant tailwind is detected on

approach, an early decision to overshoot is usually the best course of action.

Tailwind takeoffs 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 takeoff and landing performance because of the reduced headwind component and the difficulties in maintaining directional control.



Photo courtesy of Airways New Zealand

As a general rule, if the wind is 30 degrees off the takeoff/landing heading, the headwind is effectively reduced by 15 percent. If the wind is 45 degrees off, the headwind is reduced by 30 percent. A light crosswind may be either an advantage or disadvantage with respect to takeoff and landing performance, depending on whether the wind is from the starboard or port quarter.



In a helicopter with the main rotor rotating in an anti-clockwise direction when viewed from above (American designs), a crosswind from the port side will assist performance as it reduces the thrust required from the tailrotor to counter main rotor torque. The reduced power required in this situation is then available to the main rotor for increased lift.

Conversely – using the same helicopter type – if the wind was from the starboard quarter it will be pushing against the tail boom, vertical stabiliser and the tailrotor disc in the same direction as main rotor torque.

This increase in the total rotational force must be overcome by additional tailrotor 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, causing the helicopter to descend. If the pilot fails to reduce collective pitch, the rotor rpm will decay and the helicopter will descend in an uncontrolled manner.

### *Turbulence and Windshear*

The possibility of turbulence and windshear should be considered when determining takeoff and landing performance.

(Windshear is a change in wind speed and or direction over a very short distance). The presence of windshear 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 very marked in the lee of the obstruction.

In winds below 15 knots, the turbulence in the lee may extend vertically to about one third higher again than 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 windshear is likely to be present during takeoff



will require a greater power margin to deal with any unexpected loss of airspeed and 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 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 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 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 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. It is important to remember that 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, and there is thus 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 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 is 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/departure routes, obstacles, escape routes, surface, and landing aids.
- Ambient conditions at the landing zone – especially wind direction and density altitude.

If all of 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:** Do not forget that there will be situations where further calculations may be required in order to effect a safe departure from some pads that, for instance, require a towering climb from a confined area.

### **Slope**

As has already been mentioned, hovering above sloping ground will require more power than if 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 into the rotor disc is not as greatly affected, resulting in the loss of the benefits that would permit a hover IGE. More power is therefore required to



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, however, cause a loss of tailrotor 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, tree canopy, etc, requires more power and thus will reduce the IGE hover ceiling.

hover over sloping a surface – a prudent pilot would base their performance calculations on an OGE hover in such a situation.

An up-slope wind when hovering above a





## Other Considerations

### Power Checks

Conditions at takeoff/landing sites are usually 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 conducting a power check **before** committing to a takeoff or a landing.

### Prior to Takeoff

Determining the excess power available at takeoff not only gives the pilot a good idea of whether obstacle clearance will be adequate, but also what 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 takeoff can also be a useful tool to indicate a departure from 'expected' performance values. Refer to the section on power assurance checks for more detail.

The excess power in hand for takeoff 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\* commencing a vertical takeoff until maximum collective input is achieved; note the corresponding manifold pressure or torque. Sometimes the pilot may already have a good idea of this value from a power check prior to landing at the site.
- Make an allowance for a reduction in the power required to hover if a significant headwind exists, otherwise the value obtained may be misleading.
- Compare the two values. The difference represents the power margin available and indicates the type of takeoff 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 takeoff profile needs to be made.



**\* Note:** Taking off slowly avoids the possibility of encountering vortex ring state should there be less power available than expected and the helicopter begin to settle unexpectedly.

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

- Turn the helicopter into the wind.
- Hold the maximum allowable rotor rpm.
- Raise the collective until the skids clear the surface using a very 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 takeoff 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 due to an increase in the coning angle. This situation is terminal and is referred to as **overpitching**.



In the event a pilot overpitches the rotor disc, there is only one method of recovery and that is to reduce the pitch angle by lowering the collective with the throttle set at maximum. Overpitching is discussed again later in the booklet.

Refer to your helicopter's Flight Manual or consult an instructor/senior pilot for specific details on conducting a power check prior to takeoff.

### ***Prior to 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 takeoff, except that it is normally done in forward flight and at an altitude slightly above the landing site. It 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 manifold pressure or torque.
- While maintaining the same rotor rpm, briefly apply full power and note the corresponding change in manifold pressure or torque. (Note that it is 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 upon, 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. It is essential that this is done with pre-determined escape route in mind over a clear area with plenty of height to spare, as the amount of power required to hover OGE at high density altitudes is extremely large. The helicopter can quickly develop a high rate of descent if there is insufficient power available. Beware of vortex ring state.

### **Power Assurance Checks**

Because engine performance can deteriorate between overhauls, it is important that regular power assurance checks are done to confirm that engine output is within the manufacturer's specifications. 'Below spec' engine performance cannot always be relied upon to meet Flight Manual performance graph figures. Ensuring that engine instruments are accurately calibrated is a vital part of the power assurance process too. Incorrect readings are dangerous and can lead the pilot to think 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 takeoff will be abandoned, the load jettisoned or the landing approach discontinued if things are not going as expected.



For takeoff, this is the point at which either there is sufficient distance and height remaining to safely bring the helicopter to the hover, or to accelerate it to a safe flying speed down a pre-determined escape route (eg, in a ridge-top site situation where height can be sacrificed) should it climb slower than expected or suffer a power loss. This is particularly important for multi-engine helicopters. Plan to clear obstacles in the climbout 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 fail to achieve adequate climb performance after liftoff. It is also important to have a good idea where to put the load down if the helicopter develops a higher-than-expected rate of descent 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 abandon the approach while you still have translational lift should you not be happy with it. As for takeoffs 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

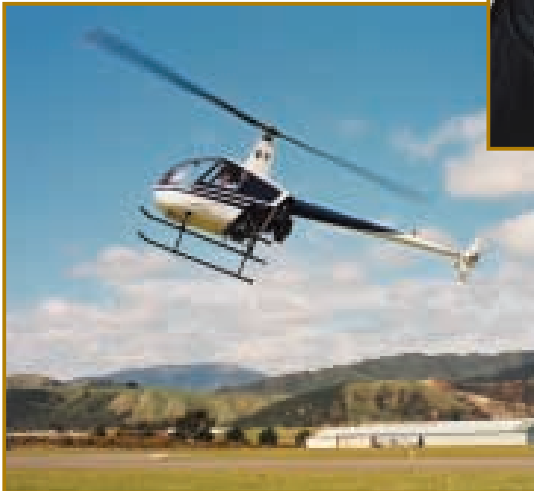
Accurate speed control after takeoff is important when it is critical to achieve best-angle-of-climb performance out of your machine for obstacle clearance.

For landing, good speed control is important so that a stabilised approach can be flown. This is particularly so as the transition from translational lift to ground effect is made – especially when making a zero-speed landing. Get too slow too early, and the helicopter may develop a high rate of

descent. Get too fast, and large or rapid control inputs maybe required to dissipate the inertia the helicopter develops.

### Overpitching

Overpitching is an extremely dangerous situation; the engine can no longer provide sufficient power to overcome the drag on 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. If not corrected quickly by



the pilot, a dangerous rate of descent will develop; there may be insufficient time to recover if operating close to the ground. Recovery techniques 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 that they have failed to determine whether or not the proposed operation was within the helicopter's performance envelope. It also normally means that they failed to conduct an adequate power check at the operating site prior to committing themselves.

Overpitching can be avoided if the pilot plans ahead and does the necessary performance graph calculations and backs them up with a power check at the operating site.



## 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, it is important to ensure that the recommended maximum performance takeoff technique is always used when operating out of a confined space, which includes flying the climbout 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 as to what takeoff or landing technique you should be using where performance is a consideration. Consider undertaking some dual revision if you are not particularly current.

## Rotor Condition

Deposits on the main or tail rotor blades, such as raindrops, spray residue, insects, dust, and pollen can have an effect on the laminar airflow over them, significantly reducing lift production. The presence of frost also affects lift production, as do minor nicks or dents.



It is vital to keep all rotor surfaces damage-free and clean to ensure maximum performance, because you never know when you might need that extra performance. Downtime spent cleaning rotor blades is always time well spent.

## Contingencies

Even after having worked out your helicopter's takeoff, 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 much greater than anticipated due to surface heating, you might not be as current as you think you are, and so on. As previously noted, many Flight Manual performance graphs are somewhat optimistic and are based on test data from a brand-new machine being flown by an experienced test pilot – all the more reason to add a contingency.

When the numbers are looking tight, it is

suggested that you always factor a contingency of at least 10 percent into your calculations.

## Know Your Helicopter

The importance of being thoroughly familiar with your helicopter's performance capabilities cannot be stressed enough. 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 is 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

#### Takeoff Performance Example

Let's work through a takeoff performance example using the H269C IGE hover ceiling chart (Figure 3) provided on page 29. 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?

**Gross weight:** 930 kg (assume full fuel tanks)

**Temperature:** +25°C @ sea level

**QNH:** 1003 hPa

**Wind:** nil

**Takeoff site elevation:** 5,300 feet amsl (there are no obstacles of note on the climbout)

**Surface:** flat short grass

### Workings

**Step 1.** The first thing we need to do is to calculate the site's **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 takeoff site elevation of 5,300 feet. Do we add it or subtract it?

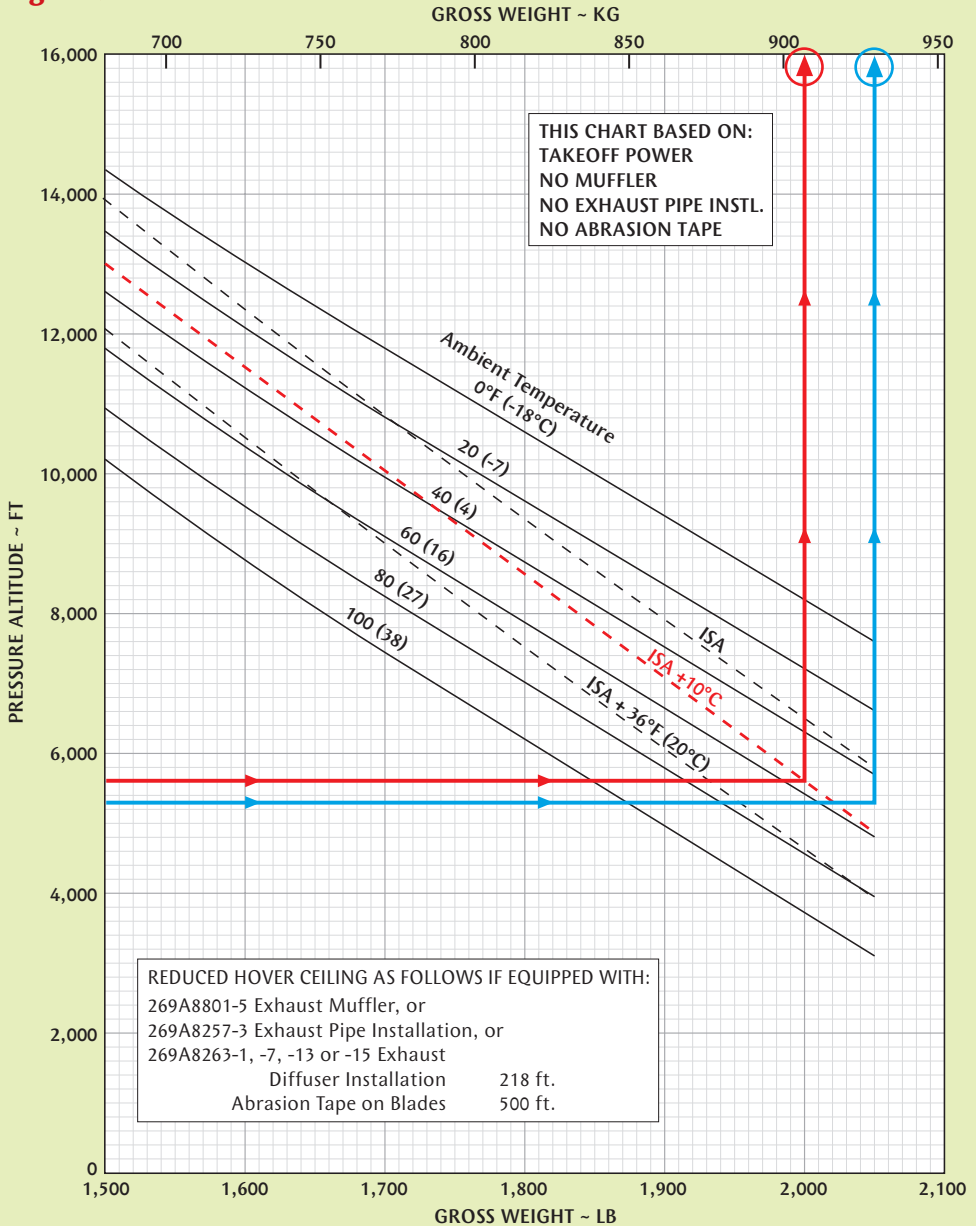
Because the pressure today is **lower** than standard (pressure decreases with altitude, 1003 hPa being found at 300 feet amsl on a standard day) we **add** the figure to takeoff site elevation, arriving at a pressure altitude of 5,600 feet.

**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 5,600 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 5,600 feet.

# SCHWEIZER 269C Helicopter IGE Hover (3,200 rpm) Ceiling Graph (Takeoff Performance Example)

**Figure 3**



**KEY** ○ Maximum permissible weight to hover IGE at pressure altitude 5600 ft in ISA +10°C      ○ Maximum permissible weight to hover IGE at 5300 ft elevation in ISA condition



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 density altitude. You may wish to make an allowance for this when entering the temperature.

Carefully draw in 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.

**Note:** If we had a reading of what the actual air temperature was at the takeoff 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 5,600 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's 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 takeoff site under these conditions, but you would not have much excess power available to takeoff. However, if you were to off load some fuel (assuming no adverse effect on safe endurance) or make two trips you would be considerably lighter. It would be reasonable to assume that you could takeoff safely at this new weight, but this would need to be confirmed with a power check prior to taking off at the site. This would tell you what kind of takeoff 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 (Figure 4) provided on page 32. Again, the red line relates to the data supplied below and the blue line provides a comparison for 'standard' conditions.

You are the operator of a Bell 206B3 who has been approached by a broadcasting company 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?

It 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 on the safe side. Since the operation involves a sling load, the calculations will need to be based on a hover OGE.

**Gross weight:** 1455 kg (assume full fuel)

**Estimated site ambient air temperature:** 20°C

**QNH:** 1005 hPa

**Landing site elevation:** 6,700 feet amsl

**Wind:** nil

**Surface:** flat, fine scree

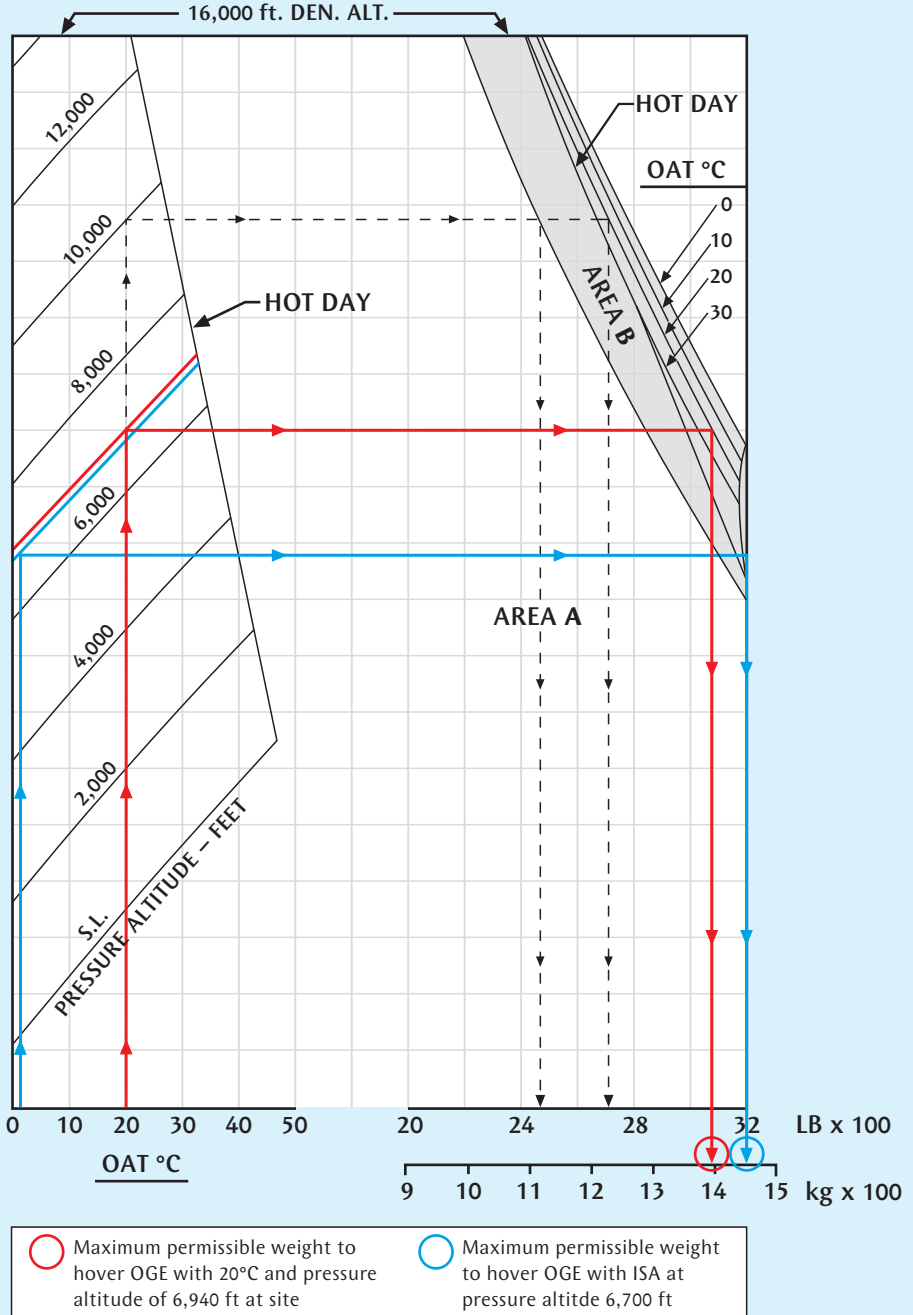
### *Workings*

**Step 1.** The first thing we need to do is to calculate the site's **pressure altitude** using the method described in the previous example. In this case pressure altitude is 6,940 feet (6,700 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 we need to determine what the **density altitude** at the site is. Our site temperature in this case has been estimated as being 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 6,940-foot pressure altitude reference line that has been drawn. The intersection of these lines indicates the density altitude at the site.

**Figure 4**

**Bell 206B3 OGE Hover Ceiling Graph (Landing Performance Example)**







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 4,000 feet.

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

In this case, the maximum weight the helicopter can hover OGE at this density attitude is 1390 kg. It will therefore not be possible to safely undertake the job at 1455 kg. Off loading approximately 80 litres of

fuel, however, will bring the helicopter weight down to 1390 kg where it would be reasonable to assume from the calculations that the job could safely carried out under the conditions specified. (You would confirm this figure with a power check adjacent to the site.) Alternatively, you may decide to wait for a cooler day with higher pressure, or a steady headwind, to do the job.

**Answers to helicopter performance problems:**

1. IGE hover ceiling would be 6,200 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.

## Conclusion

Takeoff, landing and hovering are all high-risk 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 avoided provided the pilot maintains a good awareness of the surrounding conditions, knows the performance limitations of the machine, 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.

If you **ever** have **any** doubts about the ability of your helicopter to perform the task at hand, then the prudent thing to do is to take the time to apply basic performance calculations (remembering that Flight Manual performance data can be optimistic), and to back these up with a power check at the actual site; it takes the ‘she’ll be right’ out of the situation.

Make performance calculations part of your flight if you suspect things might be tight.

### Performance Questions

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

**Problem 1.** Calculate the IGE hover ceiling given the following:

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

**Problem 2.** You are approached by a farmer to sling-load some fencing equipment onto a high ridge-top site. Is the job within your helicopter’s performance capabilities given the following?

Type: Bell 206B3  
Gross weight: 1430 kg  
Temperature: +20°C @ ridge-top site  
QNH: 1003 hPa  
Site elevation: 4,300 feet amsl

**Problem 3.** What is the maximum weight I can hover IGE at an elevation of 6,200 feet given the following?

Type: Schweizer 269C  
Temperature: +25°C @ sea level  
QNH: 1025 hPa  
Elevation: 6,200 feet amsl

**Problem 4.** A friend asks if you can fly four college students and their packs into a tramping hut in the Tararua 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 @ site  
QNH: 1003 hPa  
Site elevation: 5,800 feet amsl





GAPs are produced by the Civil Aviation Authority of New Zealand.  
*Helicopter Performance* was published in November 2002.