

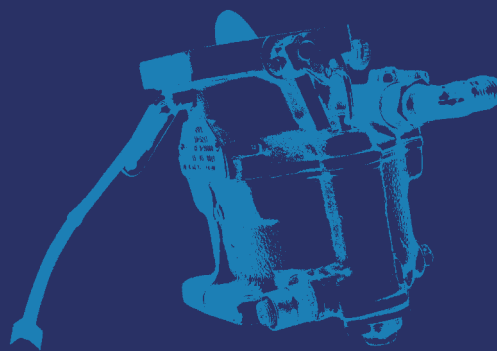
NO ICE,
THANK **YOU**





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LYC 0-540-F1B5 Engine



PROFILE

Richard Mornington-Sanford has forty years of experience in the aviation industry, 35 of these are with the Robinson product.



A CAA licensed helicopter engineer, flight instructor and Air Accident Investigator, his unique combination of expertise means that he is in demand from countries worldwide.

Richard is passionate about flight safety and devotes a considerable amount of time to that cause.

"Flight safety is predominately about the pilot's awareness and their capacity to react correctly and deal with in-flight problems. The more aware the pilot is of the aircraft they fly, the less likely they are to over react to a benign indication and potentially turning it into a life threatening situation. We tend to spend a great deal of time and effort practicing for engine failures when statistically they are not one of the main causes of fatal accidents, however practising for the engine failure **is** one of the main causes of training accidents, do not stop practicing autorotation's but do find out what kills helicopter pilots."

Richard also conducts the Robinson R22/R44 Maintenance Course and the European Robinson R22/R44 Pilots Flight Safety Course.

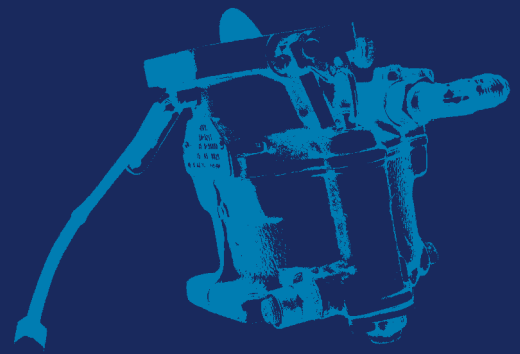
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INTRODUCTION

Richard Mornington-Sanford examines the cold, hard truth about carburettor icing in piston engine helicopters, and warns against failing to understand this potential killer.

Carburettor ice has been linked as the possible cause of fatal accidents involving piston engine helicopters fitted with float-type carburettors. This lamentable fact needs to be better understood if the risks of power loss and even complete engine stoppage are to be avoided. While carb ice is a natural, and to some degree, inevitable occurrence, pilots and operators are occasionally still failing to grasp how and why it occurs. More importantly, they are also reacting inappropriately when it does.

By its nature, carburettor icing cannot be proved to be a major cause of accidents (the evidence melts before investigators arrive), but there is enough circumstantial evidence to identify it as the cause of several recent accidents: some of them fatal. It is vital that pilots fully understand how carb ice forms. It is also important for fixed-wing pilots converting to helicopters to understand that their knowledge of the phenomena can sometimes lead them astray.

Most of the information on float-type carburettor icing available to the helicopter pilot is based on the piston engine mounted in aeroplanes (fixed-wing). Although the causes are similar, the results are potentially more catastrophic. The fixed-wing has the benefit of the airflow through the propeller that helps to keep the engine turning. The helicopter has a freewheel unit that disconnects the engine, and a loss of power can lead to an often fatal Low RPM Rotor Stall situation (Refer to RHC Safety Notice No 24). As an experienced helicopter air accident investigator, I am sure that carburettor icing has caused a number of accidents.

Under certain moist atmospheric conditions when the relative humidity is more than 50% and at temperatures of -6°C to $+32^{\circ}\text{C}$, it is possible for ice to form in the induction system, even in summer weather. However it is most likely to occur in the -1°C to $+15^{\circ}\text{C}$ range.

ICING AREAS WITHIN THE CARBURETTOR

There are two icing areas within the carburettor which give helicopter pilots the most problems:

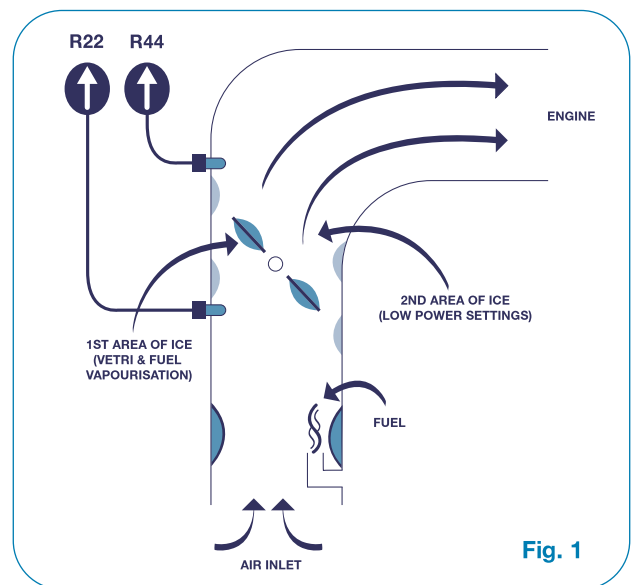


Fig. 1

The first is up-stream of the butterfly valve, due to the high air velocity through the carburettor venturi and the absorption of heat from this air by vapourisation of the fuel. The latter can be felt if you put aftershave/perfume on the back of your hand: as the volatile fluid evaporates you can feel the skin cooling as heat is extracted. This temperature drop in the mixture chamber may be as much as 20°C to 30°C below the temperature of the incoming air (see Fig 1).

The second position is down-stream of the butterfly valve, caused by the large drop in pressure when the valve moves toward the closed position, resulting in a large drop in temperature when the pilot reduces the power output (see Fig 1). 'Moist' is the key word. If the air being induced into the carburettor contains a large amount of moisture, the cooling processes can cause precipitation in the form of ice, generally in the vicinity of the "butterfly" or throttle plate. This ice may build up to the extent that a drop in power output could result, and if not corrected these conditions may cause the engine to stop and a fatal Low RPM Rotor Stall could occur.

PILOT DEFENCE EQUIPMENT

To prevent the carburettor from icing, all piston engine installations are equipped with a system for preheating the incoming air supply to the carburettor (carb heat). This will allow sufficient heat to be added to replace the heat loss caused by the venturi/vapourisation effects; thus preventing the temperature within the carburettor from dropping to or below the freezing point of water. These carburettor heat systems are essentially a scoop, tube or jacket through which the exhaust pipe from one or more cylinders is passed. This air is heated by the exhaust system and ducted into the carburettor via the air filter housing; the pilot has full control of this heated air and can select full cold, partial, or full hot via a control in the cockpit. Most helicopter systems are designed so that the air supplied for carburettor heating is filtered.



One of the main differences between the use of carburettor heat in a helicopter against that of an aeroplane is that we can use “partial heat” whereas the aeroplane pilot should only use full hot or full cold. This operational difference is due to the helicopter being equipped with a carburettor air temperature (CAT) gauge in the cockpit, which allows the pilot to monitor the temperature within the carburettor. The reason for this anomaly is that an unknown amount of partial heat can actually cause induction ice in the carburettor, particularly where there is moisture in the incoming air in the form of ice crystals, these would ordinarily pass through the induction system without a problem (ambient temperature of -10°C or below). Partial heat melts these crystals and they then re-form as ice on the butterfly valve.

INFORMATION FOR THE HELICOPTER PILOT

Typical information on the use of carburettor heat states that during take-off the carb heat control should be selected to the full cold position as the possibility of icing at wide throttle openings is very remote; so remote, that it can be disregarded. This might be true of a fixed-wing aircraft where take-off power is usually full throttle, but what about helicopters with de-rated engines? (see Fig 2).

The engines in the Robinson R22 and R44 have been de-rated so your take-off power will mean you only have partial throttle openings. You can get carburettor icing during take-off. (see Fig's 2, 3 and 4 Refer to RHC Safety Notice No 25).

Butterfly Angle vs Manifold Pressure

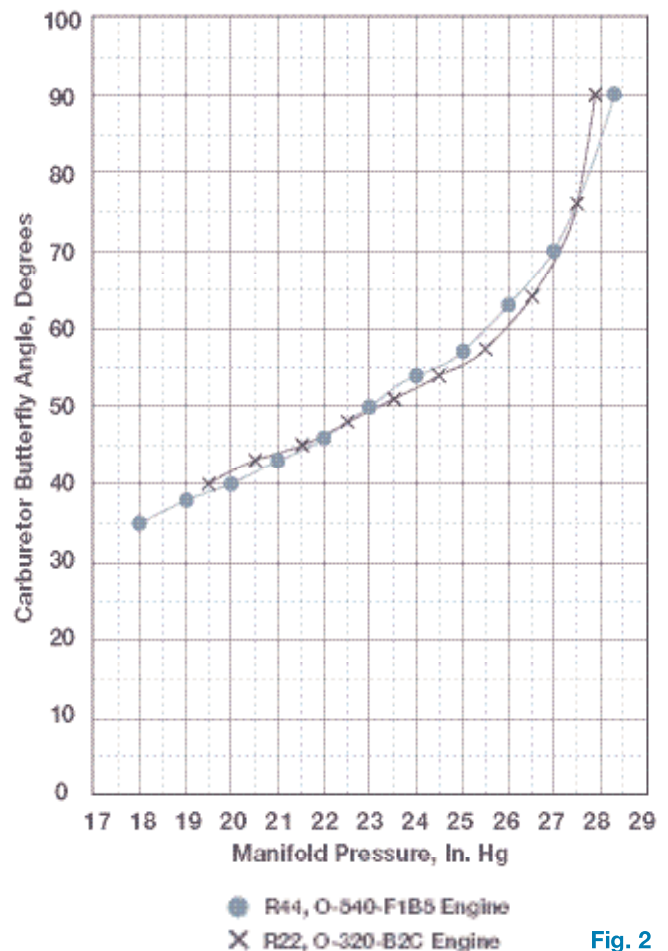
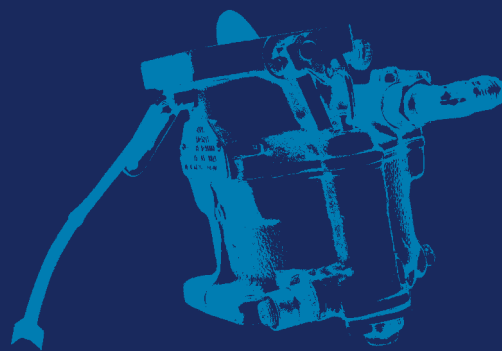


Fig. 2

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INFORMATION FOR THE HELICOPTER PILOT CONTINUED

As a helicopter pilot, you should be fully aware that the monitoring of your Rotor RPM is paramount. I would like to add that the monitoring of your carburettor air temperature is equally important.

The Lycoming engines fitted in the Robinson R22 and R44 Astro/Raven I are fitted with float type carburettors. The induction air enters through an inlet on the right hand side of the aircraft and passes through a flexible duct to the carburettor air box. A hot air scoop supplies heated air to the air box.

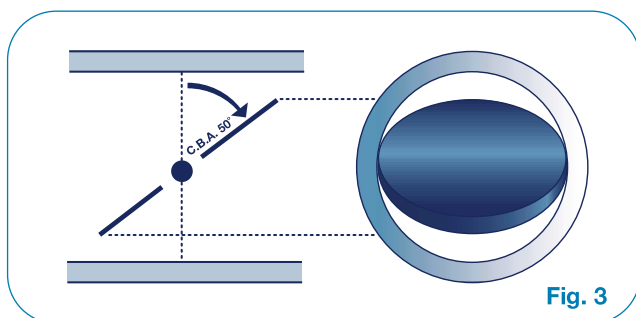


Fig. 3

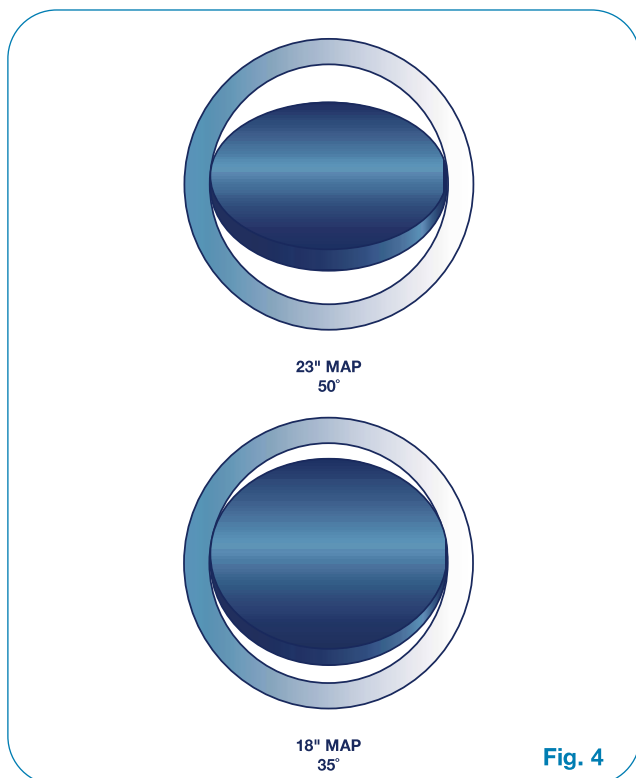


Fig. 4

A sliding valve controlled by the pilot allows either cool or warm air to flow into the box, through the air filter, and up into the carburettor.

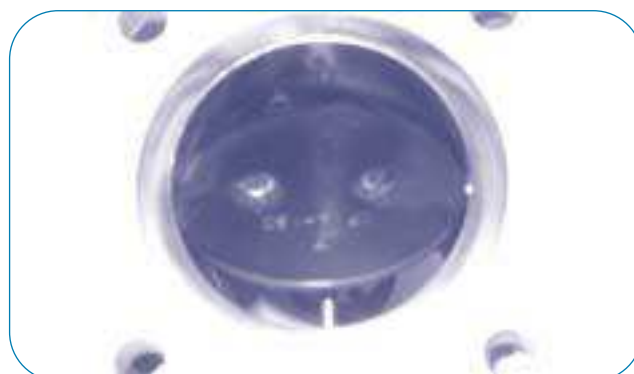
A temperature probe fitted (up-stream in the R22, down-stream in the R44) into the carburettor and wired to a gauge in the cockpit monitors the temperature of the air passing through the carburettor (see Fig 1).

The Lycoming engine fitted in the Robinson R22 helicopter is prone to carburettor icing so we need to have a good understanding of **how** it occurs **when** it is likely to occur, **why** it occurs.

How:

If insufficient carb heat has been applied, ice will build up in the area up-stream of the butterfly valve (see fig 1). As the ice chokes off the fuel/air mixture the engine will lose RPM and if allowed to progress will cause the engine to run rough and stop.

The thinking pilot will anticipate possible icing and utilise heat before the ice forms. However should the pilot fail to anticipate icing and allow it to form, they must use full heat to eliminate the ice. If your engine was running rough when you pulled full heat, then things are going to get worse before they improve. The heated air is now going to melt the ice, which will go through the induction system as water causing the engine to run rougher for a few seconds. Unless the pilot is aware of what is happening, the stress and confusion of the situation could frighten them out of using carburettor heat, and could result in losing the engine to icing.



In this very stressful situation you can inadvertently override the governor system by gripping the throttle in a 'death grip,' which will prevent it from maintaining your RPM.

You can get into a low RPM rotor stall with the governor switched on. **How good is your low RPM recovery technique?**

When:

Operating in temperate climates at any time of the year you may be flying in conditions that will cause carburettor icing.

Typical average humidity in the UK for example is approximately 65%, and the temperature range is anywhere between -6°C and +32°C. The closer the dewpoint temperature is to the outside air temperature (OAT), the more severe the engine icing conditions.

Why:

As mentioned previously, moisture in the air entering the carburettor will form as ice on and adjacent to the butterfly valve, choking off the fuel/air mixture and stopping the engine.

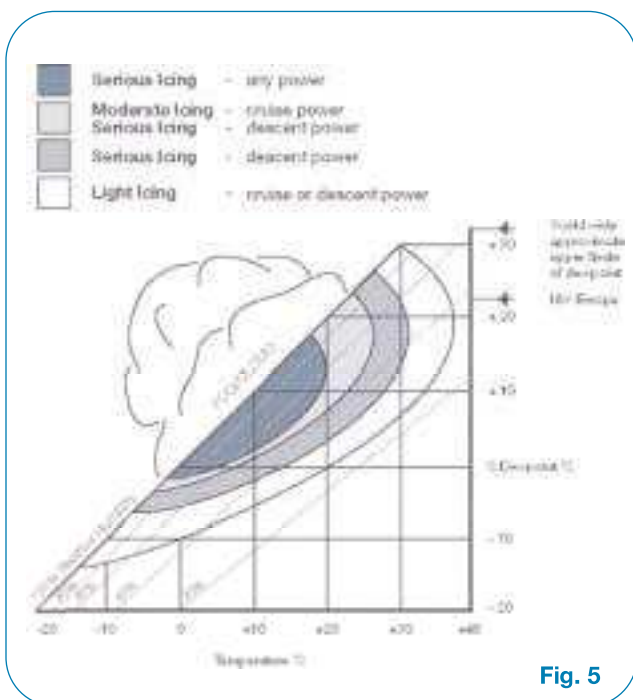


Fig. 5

PREVENTION

Ground Checks

Make sure that the carburettor air temperature gauge is accurate (this can only be done when the engine is cold), so if there is an error you are aware of it and can compensate. Check the dewpoint temperature against the OAT; this saves having to make a visual judgement by looking out of the window.

Pre-takeoff

Check for icing during your pre-takeoff checks, caution: these checks have to be carried out with the governor switched off so it is imperative that the governor is then switched on in accordance with the pilots operating hand book i.e. below 80% RPM prior to completing your pre-takeoff checks.

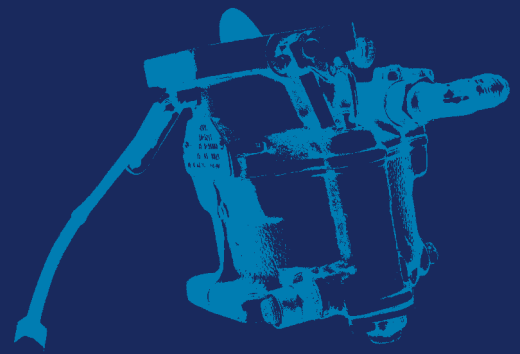
Your carburettor heat check on the ground during your pre-takeoff checks should include the following:

- Apply full carburettor heat and check that you get a rise in carburettor air temperature.
- Check the RPM: it should drop and remain at this lower RPM if you have no ice. If the RPM then recovers i.e. increases, your carburettor had picked up some ice, which has just been removed by the heat applied. When you re-select full cold you will also get a further increase in the RPM.

Hovering

Having checked the accuracy of your gauge, apply sufficient heat to prevent icing. (At least 15°C indicated on the gauge on the R22. Just out of the yellow on the R44 Astro/Raven I and more if the conditions require it). Remember you will very rarely fly in conditions where carburettor icing is not a threat. When in the hover, do not remove your hand from the collective lever to adjust the carburettor heat. Always land first as the collective lever could drop causing a dynamic roll over accident. **It has happened.** If you have been hovering over wet grass for a period of time, you may have picked up some carburettor ice. Land and clear it with full carburettor heat prior to departure.

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Climb out

Have at least 15°C indicated on the gauge, more if the conditions require. Remember your engine is de-rated so the throttle will not be fully open, unlike a fixed-wing your engine can ice up on the climb out and take-off. (see Fig 4).

Cruise flight

During the cruise, ensure sufficient heat is applied to give you an indication on the carburettor gauge of a minimum 15°C, and more if the conditions require it. Do not be afraid of using full heat if you think you need to. Lycoming states that you will not be damaging your engine with full heat if you are pulling up to 75% of rated power, and the R22 Maximum. Continuous Power (MCP) is approximately 75% of the engine's rated power. If you are flying an R22 with the carburettor heat assist fitted you may have to keep adjusting the heat to keep your pre-selected temperature. The primary concern of the pilot flying in carburettor icing conditions is not the possibility of pre-ignition or detonation from the selected heat at cruise power, but rather to keep the engine running no matter how much heat is required.

Note: In the above situations, due to the temperature probe in the R44 Astro/Raven I you will only need the gauge needle just out of the yellow.

Descent

Always apply full carburettor heat at least 15 to 20 seconds before you lower the collective lever to reduce your power. If you are flying an R22/R44 with carburettor heat assist fitted, override the system and pull full carburettor heat as above. At 200ft select pre-selected heat. The carburettor will have heat soak and the butterfly valve will be moving away from the closed position as you bring in the power, so you should not get icing during this last part of the approach. It is important that you have your hand on the collective lever as you come into the hover. You will also have approximately 13% less power available if you still have full heat selected.

WHAT HAPPENS IN FLIGHT?

When the carburettor starts to ice up, you will get a drop in RPM and a drop in manifold pressure. The ice will be building up-stream of the butterfly valve due to the venturi effect and the vapourisation of the fuel.

The R22 has a very good engine governor system which will correct for this RPM drop by opening the throttle, thus masking the ice build up (refer to RHC Safety Notice No 31). The first sign of icing the pilot might get will be when the engine starts to run rough, which could mean it is already close to stopping.

What should the pilot do?

What if the pilot merely lowers the collective lever? The butterfly valve will now be moving towards the closed position due to the correlator and ice will form on the down-stream side of the butterfly valve due to the reduction in pressure. Add this to the ice up-stream and your engine will stop.

What if the pilot just pulls full carburettor heat? Well, having just taken your hand off the collective lever your engine stops!!!

What if the pilot opens the throttle and lowers the lever? Opening the throttle will move the butterfly valve in the right direction and prevent the correlator from closing the throttle as you lower the collective lever, and it will maintain your RPM. Now you can pull full carburettor heat, and if your engine *does* stop, having less pitch on the blades will mean your rotor RPM will decay less quickly, giving you more time to establish autorotation.

Gusting/turbulent conditions

The rotor RPM is affected by wind gusts and turbulence; the rotor RPM will increase when the disc is loaded. If you have allowed ice to build-up in your carburettor, the governor, reacting to a loaded disc, will close the throttle to correct for the increase in RPM. The butterfly valve closing, plus any ice already present, could choke off your engine, causing it to stop.

The governor has a duty response system built-in so that the further the RPM is away from its governed position, the quicker it will respond to get it back. This means it could close your throttle by a large amount.

THE CARBURETTOR HEAT ASSIST SYSTEM

The system was fitted to help prevent carburettor icing incidents, however the system only applies carburettor heat as you lower the collective lever: *this is too late*. You need to apply full carburettor heat 15 to 20 seconds prior to any large reduction in power, or the engine will stop. **It has happened to me.** The system should help maintain the pilots carb heat selection, but wear in the linkage can sometimes cause a problem where power changes during cruise flight can alter the pilot's pre-selected carburettor heat selection. Its major benefit is that it reduces the pilot's workload by removing carb heat when the power is pulled in at the bottom of an autorotation or descent.



THE EFFECT OF CARBURETTOR HEAT ON POWER

The application of full carb heat will cause a power loss of approximately 13%. Aircraft engines horsepower output is checked at a corrected standard temperature of 15°C. There is a simple rule of thumb for the effect of heat on power: for every 4°C of heat above the standard 15°C there is a 1% power loss. Since the average heat source for the carb provides at least 40°C of heat above standard, this heat condition causes an average power loss of 10%. Add to this the fact that warm air is less dense, so the mixture becomes richer, we get up to the 13% power loss caused by the application of heat. In the following charts I have rounded it down to 10%.

Approximate M.A.P. variation with Carb heat

ROBINSON R22 BETA WITH - LYC 0-320-B2C ENGINE

M.C.P. - 124 BHP

Max 5 Minutes rating - 131 BHP

Air temp. rise @ full carb heat is approximately 40°C

There is an approximate 1% reduction in power per 4°C temp. increase

Therefore a 40°C temp. increase will reduce the power by 10%

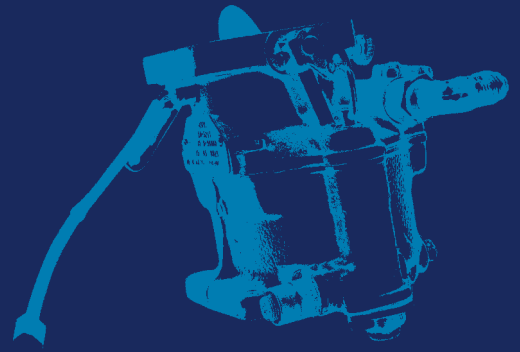
10% OF 124 BHP = 12 BHP

Per power chart in Lycoming operators manual **1 INCH** of Manifold pressure = 7 BHP

Therefore with full carb heat M.C.P. 124 BHP will occur at approximately **12 DIVIDED BY 7 = 1.7 INS** Manifold pressure above chart limit

Therefore with full Carb heat. MAX take-off **131 BHP** will occur at approximately **13 DIVIDED BY 7 = 1.8 INS** Manifold pressure above chart limit

NO ICE, THANK YOU



ROBINSON R22 BETA II WITH - LYC 0-360-J2A ENGINE

M.C.P. - 124 BHP

Max 5 Minutes rating - 131 BHP

Air temp. rise @ full carb heat is approximately 40°C

There is an approximate 1% reduction in power per 4°C temp. increase

Therefore a 40°C temp. increase will reduce the power by 10%

10% OF 124 BHP = 12 BHP

Per power chart in Lycoming operators manual
1 INCH of Manifold pressure = 8 BHP

Therefore with full carb heat M.C.P. 124 BHP will occur at approximately **12 DIVIDED BY 8 = 1.5 INS** Manifold pressure above chart limit

Therefore with full carb heat. MAX take-off 131 BHP will occur at approximately **13 DIVIDED BY 8 = 1.6 INS** Manifold pressure above chart limit

ROBINSON R44 ASTRO/RAVEN I WITH- LYC 0-540-F1B5 ENGINE

M.C.P. - 205 BHP

Max 5 Minutes rating - 225 BHP

Air temp. rise @ full carb heat is approximately 40°C

There is an approximate 1% reduction in power per 4°C temp. increase

Therefore a 40°C temp. increase will reduce the power by 10%

10% OF 205 BHP = 20 BHP

Per power chart in Lycoming operators manual
1 INCH of Manifold pressure = 12 BHP

Therefore with full carb heat M.C.P. 205 BHP will occur at approximately **20 DIVIDED BY 12 = 1.6 INS** Manifold pressure above chart limit

Therefore with full carb heat. MAX take-off 225 BHP will occur at approximately **22 DIVIDED BY 12 = 1.8 INS** Manifold pressure above chart limit

Example:

With this in mind, if the pilot calculates their MCP (124HP) 5min rating (131HP) on the **Robinson Beta II** for example, and then applies 20°C of carb heat, this will change the manifold pressure at which they will achieve those limits (124HP/131HP). They will, in effect, have to pull more manifold pressure than calculated on the Limit Manifold Pressure Placard (see above).

The **Robinson R44 Astro/Raven I** is less prone to carburettor icing. The temperature probe is located down-stream of the butterfly valve (see Fig 1). The carburettor also gets some heat soak by being enclosed by the engine cowlings.

However, still pull full carburettor heat 15 to 20 seconds prior to any large reduction of power.

The **Robinson R44 Raven II** is fuel injected, so removes the need for carburettor heat control.





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