Yakima WPA FAA WINGS Seminar:
Density altitude and aircraft performance
With Amy L. Hoover

This discussion is an introduction to some easy tips and methods you can use to better apply your understanding of effects of density altitude on aircraft performance to your flight operations. It is not a substitute for proper preflight planning and use of appropriate aircraft performance documents and limitations.

Summer is a time to slip the surly bonds and go on that adventure to the mountains for some airplane camping and fishing or hiking in the wilderness. When the mercury rises, you know your airplane just isn't going to perform like it used to. But many pilots have discovered first hand that the changes due to increase in density altitude (DA) can be significant, especially at higher elevations they encounter during trips to the mountains and canyons of the western U.S. These changes include:

- Reduction in engine horsepower and resulting loss of thrust
- Longer takeoff and landing rolls
- Decreased climb performance

These factors are inter-related. Loss of thrust means you don't have as much *oomph!* to accelerate your aircraft to it's indicated airspeed for takeoff. At higher density altitudes the true airspeed (thus the groundspeed) is higher at that indicated takeoff airspeed, which means the airplane takes more runway to accelerate to the right speed for liftoff, and do it with less horsepower available. Likewise, when you land at the same indicated airspeed you use at lower altitudes, you will have a faster groundspeed and take longer to stop. On takeoff, when you do make it off the ground, your climb performance can be quite dramatically reduced.

There are options when operating at high density altitudes. Getting a turbo-charger can solve some of the problems (except with your pocketbook). However, propellers and wings lose efficiency, even on a turbo-charged aircraft. A good choice is simply to wait until it cools down. If your summer flying takes you to the mountains, you will learn to operate in the morning or late evening when your engine and airfoils (propeller, wings, and tail surfaces) all perform better. A major item you *can* control is how you load your airplane; *you* determine what weight you will or will not attempt to carry.

When you first begin to fly in and out of higher elevation airports in the heat of the summer, do you have a good handle on how much weight reduction is necessary for safe operations? How often do you *really know* just what you can expect from your airplane at higher density altitudes? Your aircraft performance charts are a good place to start. However, many charts only give performance figures at one or two weights and some older aircraft Pilot's Operating Handbooks and Owners Manuals do not have substantial charts or data to reference. Remember also that you are not flying a new airplane, and your performance will probably not meet the expectations of the charts.

An excellent method of determining effects of density altitude is to build your own performance charts through experimentation. Load your airplane to different weight and Center of Gravity positions and record takeoff and landing distances at different density altitudes for each weight/CG combination. This requires some time commitment, but is worth it. Use a runway where you have references, such as spacing of runway edge lights, to be as accurate as possible in recording takeoff and landing distances. You will need to factor in other variables such as runway gradient, runway surface conditions, and wind. If you get the chance, attend a density altitude clinic, such as the ones sponsored by the FAA, to collect data on your aircraft performance.

This section includes some easy ways to help you think about degradation of aircraft performance with an increase in density altitude. Other factors such as runway gradient, runway surface conditions, and wind will be addressed later. First, we will take a close look at an easy and simple way to determine density altitude (DA). Once you can determine the DA quickly, then you need to know what to do with that figure, or it is of no use to you. The next part of the discussion will give you some ways to quickly determine roughly what performance you can expect from your airplane at higher density altitudes. The only items over which you have direct control in attempting to gain better performance when operating at higher elevation airstrips are (1) waiting for cooler temperatures and lower density altitudes; (2) buying a higher performance airplane; or (3) taking some weight out of the one you have. The third section addresses some ideas of how much weight you must take out to obtain better performance. Finally, there are some general "Rules of thumb" you can use to determine takeoff, landing, and climb performance for your airplane at higher density altitudes and different aircraft weights.

Determining Density Altitude (DA)

Following are two simple rules of thumb that provide a quick and easy way to determine density altitude (DA) at a given pressure altitude (PA).

Rule of thumb: To determine DA at a given PA, add 600 feet to existing PA for every 10° F above standard temperature for that altitude.

Rule of thumb: To determine DA at a given PA, add 120 feet for each 1° C above standard temp

To do this you must know the standard temperature at a given PA. The table below is a handy reference, and you will find it easy to remember the standard temperature for your home field and elevations that you use often.

Pressure altitude	Standard temperature	
Sea level	59.0° F	15° C
1000 feet	55.5° F	13° C
2000 feet	52.0° F	11° C
3000 feet	48.5° F	9° C
4000 feet	45.0° F	7° C
5000 feet	41.5° F	5° C
6000 feet	38.0° F	3° C
7000 feet	34.5° F	1° C
8000 feet	31.0° F	-1° C
9000 feet	27.5° F	-3° C

Standard Temperature at Different pressure altitudes

Let's work an example using the rule of thumb in degrees F. Suppose you want to depart from an airport at elevation 5000 feet on a summer day and the temperature is 85°F.

Example (much of Idaho and Montana):

Pressure altitude (PA)	= 5000 feet
Temperature	= 85° F
Standard temp at 5000 ft	= 41.5° F
Temp = 85 - 41.5	= 43.5° above standard

Using the Rule of thumb, round off the numbers to make it easier:

Density altitude (DA)	= 5000 + (600 x 4.4)
	= 5000 + 2640
	≈ **7600 feet**

Thus, a typical summer density altitude in much of the mountain west is over a mile and a half high *when you are sitting on the ground!*

Another example (western Colorado)

	PA	= 9000 feet
	Temp	= 70° F
Standard temp at 9000 feet		= 27.5° F
Temp = 70 - 27.5		= 42.5 degrees above standard
	DA	= 9000 + (600 X 4.3)
		= 9000 + 2580
		≈**11,600 feet**

And another (Sun River in central Oregon):

Pressure altitude (PA)	= 4000 feet
Temperature	= 90° F
Standard temp at 5000 ft	= 45° F
Temp = 85 - 41.5	= 45° above standard

Using the Rule of thumb above:

Density altitude (DA)	= 000 + (600 x 4.5)
	= 4000 + 2700
	= 6700 feet

Thus, a typical summer density altitude at Sun River, Oregon **is more than a mile high!**

In the mountains, where you will be flying at actual elevations ranging from over a mile to as much as 14,000 feet, increased density altitudes create a real problem! Do you fly an airplane whose service ceiling is only a few hundred feet above the density altitude? What will your climb rate be? These are questions you should be posing when the temperatures start to rise, and having a quick idea of the density altitude is the best starting point.

There are some options available when operating at higher density altitudes. One way to solve the problems of decreased aircraft performance would be to get a higher performance airplane, or a turbo-charger. However, any airfoil loses efficiency as the air density increases. This includes wings and tail surfaces, but the most significant is loss of propeller efficiency, which contributes enormously to degradation of aircraft performance, even on a turbo-charged aircraft. Another option is simply to wait. As it cools off the DA will decrease, so waiting until the cool of the evening, or the next morning, can solve a lot of problems; the engine and airfoils (propeller, wings, and tail surfaces) will all perform better.

The principle item over which you as the pilot have control is how you load your airplane; what weight you will or will not attempt to carry out of an airstrip at high density altitudes. But how much weight can you carry? In the following sections we will address this and present some different ways to get a rough estimate that you can use to enhance your use of weight and balance computations and aircraft performance charts to gain an understanding of the enormous decrease in performance with increase in density altitude. The first thing we will address is how much reduction in engine horsepower you are going to have due to higher density altitude.

Reduction in engine horsepower due to DA increase

As density altitude increases, engine horsepower decreases. If you know what the decrease is and how to apply that knowledge, you can determine roughly what your performance degradation will be and how much weight you may have to take out of the airplane to operate safely. Based on standard atmospheric pressure lapse rate and reciprocating engine efficiency, we can use the following:

<u>Rule of thumb:</u> A normally aspirated aircraft engine loses approximately 3.5% hp per 1000 feet increase in DA

Let's use a common airplane as an example, a Cessna 182.

Example: 230 hp airplane at the 5000 ft airport where the DA = 7600 feet

HP reduction	= 3.5% x 7.6
	= 27% reduction (approximately 73% available)
230hp x (73%)	= 168 hp available at 7600 ft DA

Another way to determine the amount of power reduction your aircraft engine will suffer is to know what you produce at full power on your MP gauge at sea level standard day. Then, determine the amount of power per inch you are producing, and calculate power reduction based on the fact that your engine will lose one inch of manifold pressure per 1000ft DA.

Example: given a 230-hp engine that produces 28" MP at full power, sea level standard day

Horsepower per inch = 230hp/28" = 8.2 hp per inch

At 7600 ft DA the engine will produce approximately 20.4" (28" - 7.6") at full power and your horsepower will be:

8.2 hp per inch X 20.4" = 168 hp available at 7600 ft DA

Either method works well in estimating your power reduction and give similar results. The amount of reduction may seem a shock at first, but it should alert you to the realities of density altitude related performance problems. If someone offered you an STC to remove the 230hp engine out of your Cessna 182 and replace it with one from a Cessna 172, you would think they were crazy! But, by operating at this increased DA you are effectively doing the same thing.

Using the examples, determine the density altitude and available horsepower for the airplane you fly at the given altitude and temperature on the next page:

Example: PA = 7000 Standard temp = ________

Existing temp = 80° F = _________ Degrees above standard

Density altitude = __________feet

HP reduction = 3.5% x ______________(DA) = ________% reduction

= _______% X sea level power

Available HP = __________________

You can reduce the amount of weight you load into your airplane to compensate for the loss of power. Your aircraft may or may not have performance charts at different weights, and you should be familiar with the difference in performance at those varying weights. The next question is, how much weight must you remove to compensate for the reduced power if you want to operate at a roughly equivalent sea level performance? One way to do this is to determine the aircraft power loading at which you want to operate, and load the aircraft accordingly.

Power loading and weight reduction

One way to get an idea of your engine performance is to compare the airplane's power loading at different altitudes. Sea level standard day power loading is defined as gross weight (GW) divided by horsepower available. In many of the newer Owners manuals or Pilots Operating Handbooks sea level power loading is given with other performance figures, but it is easy to calculate. Let’s take the Cessna 182 again:

Example: The Cessna 182 is A 2950-lb, 230-hp airplane at sea level:

$$\text{Power loading} = \frac{2950\text{lb}}{230\text{hp}} = 12.8 \text{ lb/hp}$$

If you want to get sea level power loading out of the airplane at higher density altitudes, then you would take enough weight out so that the new weight to hp ratio equals 12.8 lb/hp. To do this first compute net hp for density altitude:

From the previous example:	5000 ft PA and 85° F
Density altitude	= 7600 ft
Horsepower available	= 168 hp
Original (certified) GW	= 2950 lbs

To calculate the "effective" gross weight that will give us equivalent power loading, multiply the net hp available by the desired sea level power loading:

net hp available x SL power loading	= new GW
168hp x 12.8	= 2150 lbs

Thus to obtain sea level equivalent power loading for a Cessna 182 on a summer day at 5000ft elevation and 85° F you must remove roughly *800 lbs!!* That is equivalent *to two 180-lb passengers, two 75-lb bags, and 48 gallons of gas!*

In the space below, calculate an equivalent gross weight for sea level power loading for the airplane you fly given the following conditions:

Pressure altitude = 7000 feet
Temperature = 80°F

Density altitude = _______________ (you calculated this in the previous example)

Your aircraft
Power available = _______________(from previous example)

______________(Hp available) X _____________(SL power loading) = new GW

= _____________________lbs

You can do the previous calculation using any power loading you choose to get an approximation of the performance you can expect. For example, if you normally operate from a 3000-ft elevation airport and think the performance there is adequate for your needs, simply calculate the power loading using 3000-ft pressure altitude and standard temperature, and use that figure as your standard of comparison.

To avoid calculations, there is another easy way to approximate the amount of weight reduction necessary to gain "equivalent" performance. The following rule of thumb can give you a good estimate. In order to check the rule of thumb we used a Cessna 172 (fixed pitch), a Cessna 182 (Constant speed) and a Cessna turbo 206 (turbo). When compared, the performance figures using the rule of thumb were remarkably close to those published in the Pilot Operating handbook for those aircraft. Always keep in mind that the propeller and the wing can't be turbo-charged! You will still lose some performance with loss of propeller and wing efficiency.

Rule of thumb: To compensate for reduction in engine horsepower, for each 1000 ft increase in DA, reduce GW by:

Fixed pitch:	**3.0%**
Constant speed:	**2.85%**
Constant speed/turbo:	**2.3%**

Aircraft loading and weight are items over which you have direct and immediate control. We have looked at how to reduce the weight of your airplane to get better performance. However, you may choose to fly with a given weight and accept the decrease in performance. If so, you need to have a good idea of just what that decrease in performance is going to be. If your aircraft has inadequate performance charts, you may choose to make your own, as suggested earlier. Or, you may have to make some choices, such as flying only in the morning or evening, or making multiple trips carrying lighter loads. The next section gives some easy ways to estimate some of the parameters involved.

Takeoff performance

Determining takeoff performance can be the most critical aspect of your flight planning. You may find that your airplane can easily land at some backcountry or mountain strip, only to discover that you cannot depart with the same weight at the same density altitude.

When the aircraft is accelerated to the Indicated Airspeed at which it will take off and climb, the True Airspeed (thus ground speed) will be greater at high density altitudes. In addition, you have to accelerate to this faster ground speed with an engine that is producing less power, and a propeller that has lost efficiency, which can equate to a significantly longer ground roll! If you land somewhere and plan to depart soon afterward, you must determine your takeoff performance *before* you decide to land. Another option is to wait; if you land in the afternoon and plan to go fishing and spend the night, you will usually have a much lower density altitude in the morning for departure.

First, consider the following aerodynamic relationships:

Takeoff airspeed varies as the square root of gross weight
Takeoff distance varies as the square of gross weight

By using these relationships we can establish the following: A 10% increase in gross weight requires a 5% increase in takeoff airspeed**.**

The resulting corollary:

Rule of thumb: A 10% increase in gross weight results in a 20% increase in takeoff distance

Example: A 2100-lb airplane

Takeoff distance = 1200 feet

Add 210 lbs (a 170-lb passenger and a 40-lb bag)

New takeoff distance = 1440 feet

The rule of thumb is a quick way to estimate whether you want to try the takeoff with that extra passenger. What if you were operating out of a 2000 foot long airstrip? A 1200 foot takeoff roll is just over half the runway and should give you a pretty good margin for varying conditions and provide enough length to abort the takeoff should it become necessary (more about abort points in chapter 6). However, a 1440 ft ground roll is almost 3/4 of that airstrip and the safety margin is greatly reduced. What are some of your options? One option is to take several trips at lighter loads and shuttle gear and passengers to a longer strip that you can depart from with a heavier load. It is certainly worth the extra time and gas to shuttle back and forth than to discover too late that you did not have enough runway for the full load!

Following is another way to consider decrease in performance. Once you know how to compute your power loading, you can use the following aerodynamic relationship: takeoff distance at a fixed DA varies directly with the square of power loading. This results in the following relationships:

Rule of thumb: **A 10% decrease in power loading will reduce takeoff distance by 20%**
A 10% increase in power loading will increase takeoff distance by 20%

Example : A 3300 lb airplane with 285 hp engine

Power loading = 11.6 lb/hp
Takeoff distance = 1200 ft

If we take out 330 lbs (170 lb passenger, 40 lb bag, 20 gal gas)

New power loading = 10.5 lb/hp
New takeoff distance = 960 feet

If you were operating at a 2000 foot runway, wouldn't you rather be able to plan to get off and be flying in less than half the runway?

What if you do not want to remove any weight from the airplane? If you have loaded your aircraft with passengers, baggage, and required fuel to your desired weight, you can determine what the increase in density altitude will do to your takeoff performance. The relationships above yield the following:

Rule of thumb: At a given gross weight, each 1000 ft increase in DA will cause the following increase in takeoff distance:

Fixed pitch:	**8.5% increase**
Constant speed:	**8.0 % increase**
constant speed/turbo:	**7.0% increase**

When tested against actual performance charts, the estimates using this rule of thumb are close to the book figures. This is especially good news for those who have an airplane with no performance charts. To build performance charts, you can test your takeoff performance at a known density altitude. A good way is to use a runway with fixed distance markers, or runway lights that are spaced a known distance apart. Estimate the takeoff roll and climb over an obstacle by using ground references. Then, use the rules of thumb to estimate performance at higher density altitudes. Another way is to attend one of the FAA sponsored density altitude clinics, where they can track your airplane's takeoff from a known position and measure your takeoff and obstacle clearance distances at the existing density altitude. You can use that performance as a base line to estimate other performance figures.

Landing performance

Landing performance differs from takeoff performance primarily because when landing you only have to consider how much runway length it will take to stop the mass of the airplane traveling at a given landing speed. The effectiveness of your brakes does not change with increases in density altitude. Remember from the preceding discussion that during takeoff performance you must accelerate the mass with an engine that has lost power and you must accelerate it to a faster true airspeed to takeoff. This means that rules of thumb for landing performance are simpler, because it does not matter whether your airplane is turbo charged or normally aspirated fixed pitch or constant speed. The only thing that really matters is the weight that you are trying to stop.

Given the following aerodynamic relationships:

- Landing airspeed varies as the square root of gross weight
- Landing distance varies as the square of landing speed

We can state some corollaries.

- A 10% increase in gross weight requires a 5% increase in landing speed.
- That 5% increase in landing speed results in a 20% increase in landing distance.

The resultant is:

<u>Rule of thumb:</u> A 10% increase in gross weight results in a 10% increase in landing distance

Example: For a 2500-lb airplane

Landing distance = 850 feet

Add 250 lbs (a 170-lb passenger, 20-lb bag, 20 gal gas)

New landing distance = 1020 feet

Hopefully you will have some idea of how loading, or unloading, your airplane will affect the landing roll. Did you remember to estimate the takeoff before you landed there? What if you are operating at a weight that you don't want to change? How can you determine the effects of increased density altitude? The following will give you a good estimate:

<u>Rule of thumb:</u> At a given GW, every 1000 ft increase in DA results in a 5% increase in landing distance

The foregoing should give you some idea of how to manage your aircraft load when operating at different density altitudes. In addition, when working with a constant load, you can estimate what the decrease in takeoff and landing performance is going to be with respect to increase in density altitude. Remember that there are many other things you must consider, such as runway gradient, runway surface, wind, and condition of your tires, brakes, and engine.

Climb performance

This can be the most critical of all to understand the decrease in performance from high density altitudes. The airplane may have made it off the ground, but how is it going to perform during climb-out under hot and high conditions? You may have to gain a lot of altitude to climb up and out of a canyon, and it certainly works well to use the long river canyons to facilitate a cruise climb. But it would be a good idea to get an estimate of what you can expect to see for a rate of climb.

What about clearing obstacles immediately after takeoff? Because indicated airspeed for best angle of climb increases with altitude, best rate of climb airspeed decreases with altitude, they converge at the aircraft's absolute ceiling. Some Operating Handbooks or Owners Manuals publish the change in indicated climb speed with altitude, or you will have to interpolate the indicated speed to use for Vx and Vy with increase in altitude.

If the airplane you fly does not have adequate climb performance charts, you can estimate your best rate of climb airspeed with increase in density altitude. A simple study of the four forces of flight shows that an aircraft in steady state, un-accelerated flight requires a certain amount of thrust to oppose drag and maintain level flight. This holds true at any airspeed, for example when flying level at Vy. If you compared several different aircraft performance figures, you would find that for most GA aircraft the power required to provide thrust for level flight at Vy is between 40 - 55% of total sea level available horsepower.

An airplane climbs due to *excess* thrust, which is left over after you have enough to maintain level flight at a given airspeed. However, an aircraft engine loses about 3.5% power for every 1000 ft increase in density altitude, so the excess power quickly diminishes to reduce the rate of climb (ROC). The following rule of thumb can be used to calculate climb rate at a given weight:

<u>Rule of thumb:</u> $\dfrac{\textbf{excess hp x 33,000}}{\textbf{gross weight}}$ **= ROC**

The units are left off the above equation, but the number 33,000 is derived from the definition of one horsepower, which is the force required to lift 33,000 lbs at the rate of one foot per minute

Another way to determine what your rate of climb will be is to simply experiment by loading your aircraft, recording the density altitude, and using the vertical speed indicator in your aircraft to determine the speed that will give you best rate. Is this reduction in climb rate important? You bet it is! Let us look at an example from the NTSB files. Following is the body of the NTSB accident report for an airplane that departed the Salmon, Idaho airport in July of 1991. The elevation of the Salmon airport is 4045 feet MSL, and the temperature that day around the time the aircraft departed was approximately 92°F in Salmon.

NTSB accident #SEA91FA183
Salmon, ID July 22, 1991
Aircraft: Cessna 177RG Injuries: 4 Fatal

> "The pilot departed southbound from the Salmon, Idaho airport after a refueling stop. A witness saw the aircraft enter a canyon south of the airport at low altitude. Subsequently, it collided with the east side of the canyon after turning back toward a northerly direction. During initial impact the right wingtip and nose of the aircraft collided with a 30 to 35 degree rising slope. There was evidence the aircraft was still angled toward rising terrain when the accident occurred. The accident occurred at an elevation of about 5600 ft, about 11 mi south of the airport. Leading edge gouges and chordwise scratches were noted on the propeller blades. The throttle, mixture, and propeller controls were found in the full forward position."

Was it possible that the pilot of the Cardinal was expecting to get a better climb from his airplane? At sea level the airplane has a good climb rate, but what the rate of climb (ROC) at the higher density altitude? The next page gives the calculations to show this.

Example: Cessna cardinal RG — GW = 2800 lbs
engine (IO360) hp = 200hp
SL ROC = 925fpm

Excess hp used for climb at Vy $= \frac{\text{ROC x GW}}{33{,}000} = \frac{925 \times 2800}{33{,}000}$ **= 78 hp at SL**

Total hp available at sea level =200 hp

excess required for climb Vy = 78hp

Used to maintain level flight at Vy = 122hp

The above shows that at the airplane requires 122 horsepower just to maintain level flight at Vy airspeed. Any power that is left over can then be used to produce excess thrust to produce a climb. Using a standard temperature lapse from the 92°F temperature reported at Salmon, the temperature at the altitude the cardinal crashed (5600ft) was 87°F, which results in a density altitude of about 8420 ft. Take a look at the excess horsepower the cardinal had available at that density altitude:

Horsepower lost = 3.5% x 8.5
= 30% = 70% available
Hp available = 70% x 200hp
= 140
Horsepower needed to
maintain level flight at Vy = 122 hp
Excess available for climb = 18 hp

The airplane had only
18 horsepower!!
left over for climb!!

Using the horsepower/climb rate equation for the Cardinal at that DA:

$\frac{18\text{hp} \times 33{,}000}{2800\text{lb}}$ = ROC = **212 fpm**

Thus roughly 200 feet per minute was about the best climb rate the airplane would be able to achieve at that density altitude. That would include some of the following assumptions:

- The airplane was not over gross weight
- The mixture was set for best power
- The engine was tuned to max proficiency
- The pilot maintained Vy
- No excess loads were imposed due to maneuvering

There is no way to definitively answer many of the questions that arise from this accident, but take a look at the NTSB report again:

"The throttle, mixture, and propeller controls were found in the full forward position…"

"…it collided with the east side of the canyon after turning back toward a northerly direction"

The engine was probably producing less than full power because the mixture was not leaned properly for density altitude (more about that in the next section) and the aircraft might have had some extra loads due to maneuvering. Below is what the NTSB identified as the probable cause of the accident:

> *"Probable cause:* *Improper inflight planning and decision by the pilot, and his failure to maintain sufficient altitude and clearance from mountainous/hilly terrain".*

Based on the foregoing discussion, possibly improper *preflight* planning might have played a factor, because the rate of climb could have been determined from the aircraft performance charts, or calculated based on the power available at the density altitude. If you are in doubt about whether you will be able to get satisfactory climb performance from your airplane, don't go until you know what your options are. The possibilities would include waiting for the temperature to drop and the density altitude to decrease, taking weight out of your airplane, or climbing out up or down a canyon or valley that has plenty of room.

Leaning the mixture at high density altitudes

As air density decreases with increase in altitude or temperature, you ***must*** lean the mixture in order to obtain the optimum fuel to air ratio needed for your engine to run at maximum available power. You should always refer to your Operator's Manual for recommendations on when to lean the mixture. Both Lycoming and Continental recommend leaning above 3000 feet density altitude for most of the normally aspirated engines you will fly in general aviation aircraft. Most of the airports you will use in mountain and canyon areas such as the Idaho backcountry are over 3000 feet actual altitude, and density altitudes can range up to 10,000 feet on the ground. When cruising above the mountains your density altitudes can be much greater on a hot day. That means you will have to lean the mixture for ground operations as well as takeoff, climb, and cruise.

When the temperature is well above standard you will have to lean the mixture immediately after engine start. If you don't lean during ground operations, spark plugs can foul pretty quickly. If you have landed at an airstrip and plan to depart within a short time, when you start back up again simply lean the mixture to the same position that you had when you landed.

When you lean for takeoff it is best to follow the recommendations in the Pilots Operating Handbook or Owner's Manual for your aircraft. Most manuals suggest leaning the mixture at 75% power or more. If you fly a fixed pitch propeller, during your run-up you should set the tachometer to 2000 RPM or more to lean the mixture. For constant speed propellers, set the manifold pressure at lest into the green. Many operators recommend leaning at full power, but if there is a lot of dirt and debris on the taxi and runway surface you won’t want to operate at full power while sitting still. If you have an EGT gauge, you can lean it according the manufacturer's recommendations. Most recommend leaning to 50-75 degrees rich of peak RPM. If you have no EGT, you should lean the mixture until the engine begins to run rough, and then set it slightly richer. On many small planes you can use the "calibrated finger method"; lean the mixture until the engine runs rough, then push it back in about one to two finger widths. If you plan on doing a long climb you might keep it slightly rich during the climb to help with cooling, but remember you will have some power loss. It would be better to do a cruise climb (discussed in chapter 6), if possible, to help with engine cooling and increase visibility.

With turbo charged engines, set the mixture for takeoff and carefully monitor the fuel flow gauge during takeoff and climb. You may need to adjust the mixture immediately to avoid overboosting the fuel flow, especially on the first flight of the morning. On climb out use the manufacturer's recommendations for fuel flow and power settings.

During level off and cruise lean the mixture normally. If you are doing a long gradual descent, remember to enrichen the mixture slightly every 1000 feet or so as you descend.

There have been many aircraft accidents in the mountains where the NTSB reports read "the throttle, propeller, and mixture controls were in the full forward position". Too rich a mixture can be deadly because it robs your engine of the precious power it has left. If you set the mixture too lean, you can overheat the engine, especially in the hot summer. You need to develop the habit of constantly monitoring and correctly leaning the mixture at high density altitudes. An EGT gauge is a cheap and effective insurance policy that can go a long way toward more safe and efficient operations that are kind to your engine.

