PILOT'S GUIDE

FOR INSIGHT G1

PLEASE READ INSTRUCTIONS
COMPLETELY
BEFORE PROCEEDING

Insight Instrument Corp.

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Warranty and Service

The Insight Instrument Corporation 610C Graphic Engine Monitor system (G1) is warranted against defects in materials and workmanship for one year from date of purchase.
Insight temperature probes are warranted for one year or 1000 hours which ever comes first.
Insight will at its option repair or replace without charge those products that it finds defective.
Insight will not be responsible for repairs required by improper installation, unauthorized maintenance or abuse.
No other warranty is expressed or implied. Insight is not liable for consequential damages.

Technical Support

If you have difficulty installing or using a G1 system, please read the G1's documentation.
Every G1 system is shipped with complete instructions for installation and use.
The answers to many technical questions can be found in this booklet, or the G Series Installation Manual. Insight provides customer support free of charge for as long as you own the instrument.
If you have any questions concerning G1 operation do not hesitate to call.

The Customer Service department accepts calls Monday through Friday between 9 am and 5 pm EST.
Be sure to have your instrument model number and serial number(s) ready when you call.

Insight Start Splash Screen

G Series Function Comparison List

	G1	G2	G3	G4	G4 Twin
	Shipping	Shipping	Shipping	Shipping	Shipping
EGT	x	x	x	x	x
CHT	x	x	x	x	x
TIT	1 Turbo	1 Turbo	1 or 2 Turbos	1 or 2 Turbos	1 or 2 Turbos
Probe Diagnosis	x	x	x	x	x
SD Card Receptacle	x	x	x	x	x
Field Updateable	x	x	x	x	x
Data Logging (SD Card Included)		x	x	x	x
Fuel Flow		x	x	x	x
Fuel Flow Totalization		x	x	x	x
RPM			x	x	x
OAT		x	x	x	x
Buss Voltage		x	x	x	x
Manifold Pressure			x	x	x
Oil Temperature			x	x	x
Oil Pressure			x	x	x
Carb Temperature	x Extra	x	x	x	x
Lean/Rich of Peak Margin	x Basic Only	x	x	x	x
Fuel Injector Balance Analysis		x	x	x	x
EGT Variation			x	x	x
HP			x	x	x
G-Force / TO Performance			x	x	x
Turbulence			x	x	x
GPS and TAS 1000 Interface			x	x	x
Vibration			x	x	x

G1 MONITORING

The Bar-Graph Display Screen

The Exhaust Gas Temperature is displayed in white bar graph form and is interpreted much like a conventional mercury thermometer. The higher the bar, the higher the temperature.

The cylinder head temperature is displayed in green single bar format. During normal operation it shows as a green illuminated bar in the lower half of the bar column. Since EGT is normally higher than CHT, the green bar which represents CHT is on top of the white illuminated EGT bar and stands out clearly.
However, when the engine is shutdown, the EGT quickly drops to zero and the cylinders remain warm for sometime.

The G1 provides a reliable indication of cylinder head temperature even with the engine shut down.
Should an EGT probe fail, the entire EGT column for that cylinder will go blank, and the numeric indication will show --- that is dashes, but the CHT bar will still remain green.

The failure of one probe will not affect the display of any other probe.

Main Screen Description

Each cylinder has its own display column that displays both EGT and CHT simultaneously.
The columns are numbered with cylinder number. Both temperatures are displayed graphically and numerically.
Numbers below the column are color keyed actual temperatures as shown on the bar.
CHT is shown in green when in allowable range and then the bar and numeric indication turn red when exceeding the redline limit. A red line also indicates the CHT limit across the bar at the appropriate height.
During leaning the EGT column rises pushing the peak indicator above it.

The peak indicator is just a box of column width that remains at the maximum temperature reached during leaning.
Once the column drops below peak a new temperature difference numerical indication appears in the box showing the temperature difference of the current temperature below the peak. As each cylinder goes just past peak the fuel flow at peak is displayed in black in the top of the column. Ideally all cylinders will peak simultaneously but of course they won't.

The peak indications may be reset by pushing the bottom knob to re-lean the engine.

NOTE: For leaning instructions always consult the Aircraft's Operations Hand Book.

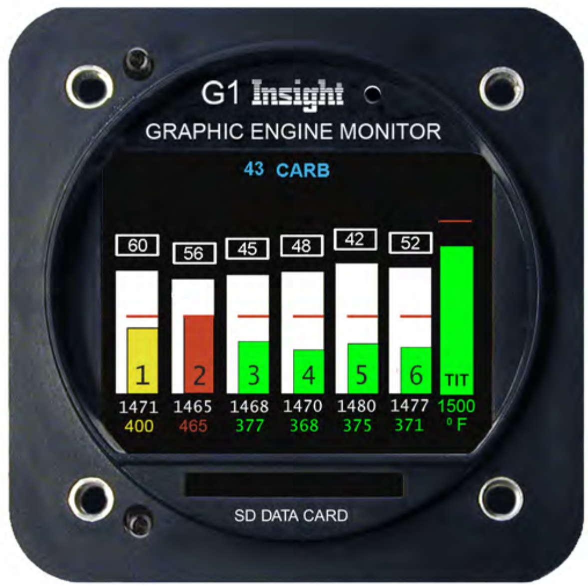
G1 Screens In Order

NEW WITH G1 SOFTWARE UPDATE 2.22

Push and hold in top button at power up you will see the serial, software number screen then the G1 brightness configurable screen and follow onscreen instructions.

If you turn on G1 and do nothing the G1 will display the main monitor screen.

1a - Main Screen



1b- Lean Screen

(Part of main screen)
Push bottom button to refreash monitor screen and to make lean boxes disappear
Push and hold bottom button for max brightness

2 - Probe Diagnostic Screen

Push top button once to get to probe screen and push again to go back to main monitor screen.

There are only 2 pages on G1
Main monitor page and probe diaonostic page.

NOTE:

To check brightness use incandescent light source to shine on GSeries instrument face.
LED and fluorescent will not work because of the lack of infrared in beam.

G1 Color Graphic Engine Monitor

First Flight With The G1

Now that the day is finally here for you to fire up your new G1 and take it for a flight you are probably eager to explore all the new functions. Before you take that first flight a few minutes should be invested to check the installation of the instrument. We recommend you read through this section once first before stepping into the cockpit.

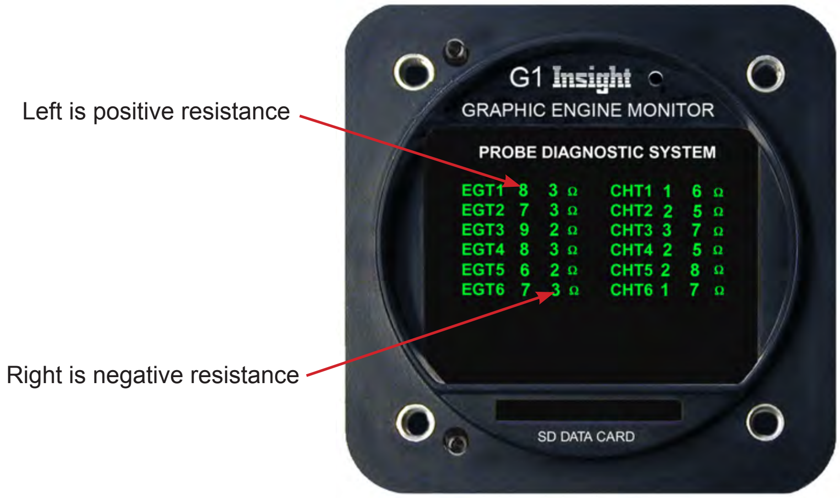
With the avionics turned on, the G1 will power up and present its title screen. During this period the user may press and hold the top button to enter probe diaopnostic screen mode if desired. Most of the configuration is pre-entered for you at the factory. After the title screen is displayed for a few seconds the main temperature bargraph display appears.

The digital temperature indications will immediately begin to increase, although it will take a little while for the CHT bars to climb due to the thermal mass of the cylinders. Likewise, EGT columns may not appear until the throttle is advanced to fast-idle.

If all looks well prepare to do your run-up. The G1 comes from the factory already set up and ready to go right out of the box. We have preset the EGT bar heights to accommodate a range of EGT temperatures that is appropriate for an average user's engine. But what if you have a turbo-boosted engine that runs hotter than average, or you were forced by mechanical clearances to put the EGT probes further down the exhaust tubes than you would have liked which leads to lower reported EGT readings? The factory settings for EGT heights may then be inappropriate for your airplane.

After taking off and reaching cruise altitude you will get your first opportunity to try the special lean mode functions. The new lean mode is easier than ever to use and tells you exactly how far the EGT's have dropped since they peaked, whether you are on the rich or lean side of peak, and what the fuel flow was during the peak. To reset the lean mode and start again just press and hold the bottom button. Remember to always begin well rich of peak EGT or you will not get a true indication of where peak is. A more complete description of the leaning process may be found in the "Description of Main Screen" section of this document.

PROBE DIAGNOSTIC Screen



Typical single engine 8 foot harness display setting on G1 above.

The probe diagnosis page indications are in green only.

Each temperature probe consists of two wires, a positive lead and a negative lead. The two numbers next to each identifier show the resistance in Ohms of each lead.

For example, the line EGT1 8 3 means the positive lead of the EGT1 probe has 8 Ohms resistance, and the negative lead has 3 Ohms resistance.

When the probe is new, it will have relatively low resistance.

As the probe ages, it's resistance will slowly go up. Eventually, the probe will measure outside the pass/fail 20 Ohms.

One other point to consider is that the longer the wiring to the probes, the higher its resistance.

Every foot of EGT wire adds 1.7 Ohms/ft for the + lead and 0.8 Ohms/ft for the - lead. Every foot of CHT wire adds 0.8 Ohms/ft for the + lead and 1.2 Ohms/ft for the 0 lead.

G1 Operating Procedure

Since the introduction of the Graphic Engine Monitor in the early 80's a new leaning procedure has been developed.
Once frowned upon, leaning past peak to operate on the lean side in cruise is now widely used to save fuel.
Since leaning with reference to temperature was first used in the early 50's, the distance from peak has also been used to define a mixture setting. The term "75° rich" is universal and means 75 degrees lower than the peak temperature on the rich side. Leaning has always employed a relative number referenced to peak temperature.
It is the only consistent metric available because the absolute temperature varies with altitude, power setting and outside air temperature.

The Graphic Engine Monitor (G1) is ready to operate the moment electrical power is applied.
Within seconds after starting the engine, the white EGT bar graph columns will begin to appear on the G3 display.
Each column corresponds to the Exhaust Gas Temperature (EGT) of a cylinder. The lowest exhaust gas temperature that can be displayed by the G1 is 800° F. In some engines, the throttle will have to be opened to the fast idle range to get an EGT indication for all cylinders.
As the cylinder heads begin to warm up, the display will indicate Cylinder Head Temperature (CHT) for all cylinders as a smaller green bar in each EGT column. A horizontal red line across each column represents the maximum allowable CHT.
Digital numbers below each bar graph column indicates the exact EGT and CHT for each cylinder.

The G1 offers a unique new function that facilitates leaning on both the rich and lean side of peak.

In previous generation instruments the peak temperature was used behind the scenes to control flashing of a column to identify peak, but it was never displayed to the user. The new instrument doesn't display the peak temperature but goes one step further to display the distance from peak on either the rich or lean side. This matches the mind set of pilots since the 50's so it's what the pilot really wants to know in first place. Previously the pilot had to remember the bar position and move the mixture to drop a few bars to enrich the mixture. Now the pilot may reference the temperature difference display directly.
The temperature difference information is calculated relative to peak EGT so it is only available for display during leaning after peak has been reached. After reaching peak a column width box appears on top of the EGT column containing the temperature difference from peak. The instrument incorporates fuel flow analysis to also determine which side of peak the mixture setting is on. It prefixes the temperature with an R for rich or L for lean.
It further distinguishes Rich and Lean by color. The box and number are in white on the lean side and cyan on the rich side.
The pilot may decide to operate at a certain temperature delta and tune the mixture until the desired number is in the box.
Precise leaning to a predetermined setting can be as simple as moving the mixture until all the boxes turn solid.

Main Screen Description

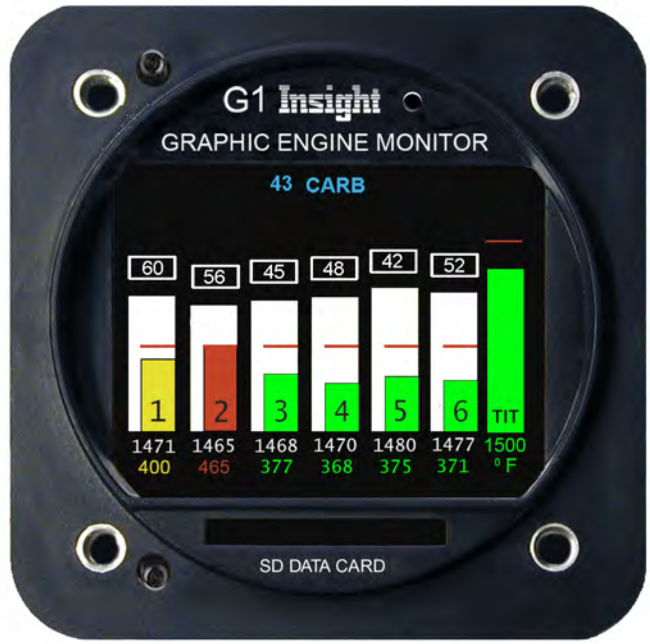
Each cylinder has its own display column that displays both EGT and CHT simultaneously.
The columns are numbered with cylinder number. Both temperatures are displayed graphically and numerically.
Numbers below the column are color keyed actual temperatures as shown on the bar.
CHT is shown in green when in allowable range and then the bar and numeric indication turn red when exceeding the redline limit. A red line also indicates the CHT limit across the bar at the appropriate height.
During leaning the EGT column rises pushing the peak indicator above it.

The peak indicator is just a box of column width that remains at the maximum temperature reached during leaning.
Once the column drops below peak a new temperature difference numerical indication appears in the box showing the temperature difference of the current temperature below the peak. As each cylinder goes just past peak the fuel flow at peak is displayed in black in the top of the column. Ideally all cylinders will peak simultaneously but of course they won't.
The variation in the fuel flow numbers will identify how close they are.

The peak indications may be reset by pushing the bottom knob to re-lean the engine.

NOTE: For leaning instructions always consult the Aircraft's Operations Hand Book.

Detect Peak



The basic G1 cruise-leaning procedure is as follows:

Establish cruise altitude and cruise power. Make initial trim adjustments, etc. as needed to establish cruise.
Perform a coarse leaning or preliminary leaning of the engine until the fuel flow is a couple of Gal/hr more than the normal cruise indication. Pause for two minutes to allow the engine to stabilize and cylinder head temperature to return to normal. It is advisable to allow up to five minutes for the turbocharger (if so equipped) to stabilize in output before attempting final leaning.
During this time you can make final trim adjustments to the airplane, reset cowl flaps, etc.
Press and hold bottom button to reset lean mode.
Now slowly lean the mixture until one of the EGT lean boxes appears at the top of the EGT bars.
This final leaning should take about five seconds.
The first lean box to appear on top of the EGT bars column of bars identifies the leanest cylinder (the first to reach peak EGT).
Continue leaning until the lean boxes appear on all cylinders.

Note: Engine manufacturers differ in their approval of operation at peak. Lycoming recommends operation at peak for power settings of 75% and less while Continental recommends operation at peak for power settings of 65% and less.
Do not lean to peak EGT power settings greater than those recommended by the manufacturer.
This procedure may not be applicable to all engines. In some aircraft the mixture may be dictated by other parameters.

Restarting The Leaning Process

The use may restart the leaning process and reset the peak indications at any time by pushing the bottom button, the indications will disappear. The user should always enrichen the mixture to the rich side of peak and lean from there, for proper detection of peak EGT.

Leaning in Cruise

The G1 is ready for leaning without any user action. If necessary press and hold the bottom button to clear any peak temperature boxes. As the pilot leans the engine the bars will rise then fall leaving a peak temperature box behind. This box will show the distance in degrees from peak and whether the mixture is rich or lean of peak. This is a simple and easy way to lean correctly and precisely.

Leaning Normally Aspirated Engines in Climb

Most normally aspirated aircraft benefit from mixture leaning during climb with less plug fouling, better engine performance, smoother operation and increased economy. The full throttle, full rich mixture setting is designed to provide an enriched fuel flow for proper engine cooling during takeoff at sea level on a standard day. As the aircraft climbs, the air density decreases causing an effective enrichment of the mixture, eventually robbing the engine of power.
Leaning in climb is advisable for best performance and will result in a cleaner engine and easier cruise leaning later on.

After safely clearing the field, observe the location of the tops of the bars on the G1.
As you ascend, the effective mixture enrichment that results from the decreasing air density causes the EGT reading to fall. Observe one column as a reference. When the reading drops, lean the mixture until the reading goes up, restoring the bar. Repeat this procedure each time the EGT reading drops due to ascent into less dense air to ensure that highest EGT.
Aircraft equipped with fuel flow gauges may have altitude reference marks to guide leaning during climb.
This procedure for leaning in climb does not apply to turbocharged engines which do not experience the same air density variations due to altitude.

Leaning the Engine in Cruise without Lean Mode

There are occasions when the pilot may wish to lean manually. It is informative on the first G1 training flight to lean the engine without Lean Mode to get a feel for the instrument. As you lean, the bars will rise, reach a maximum, and then fall at the onset of engine roughness. If you lean too far the engine will stop. Short flights in high traffic density Terminal Control Airspace (Class B Airspace) demand maximum pilot attention to traffic avoidance.
When busy, the pilot may lean quickly by watching the bars rise and stopping when they are still below the normal average indication. This procedure will be within a gallon or two per hour of the optimum mixture setting, and can be used as a temporary measure until time permits using the complete leaning procedure described below.

Leaning by Turbine Inlet Temperature

Some turbocharged engines are designed to be leaned by reference to Turbine Inlet Temperature (TIT).
This may imply that the TIT is the first temperature to reach redline and is the overall limiting factor in the leaning procedure. Some manufacturers may put a limit on the TIT to increase detonation margins. In general, turbochargers are very much alike and most manufacturers specify a redline of 1650° F. Some operate as high 1750° F.
Because indicated temperature is largely dependent on probe placement and exhaust flow, it may not be the same as that experienced by the turbo.
Aircraft manufacturers have very likely taken this into account when deciding on the official TIT redline.

Leaning Restrictions

Some aircraft have restrictions on leaning that must be observed. The recommendations of this manual are not intended to supersede any specific requirements for engine operation as stated by the aircraft or engine manufacturer.
The pilot should consult the Pilot's Operating Handbook and follow the manufacturer's recommendations.
These restrictions typically, (but not exclusively) apply to aircraft with marginal cooling airflow at high altitude or high angles of attack or turbocharged engines where concern over turbine inlet temperature, compressor discharge temperature, detonation margin, or cylinder head temperature must dictate mixture settings.

Using G1 On The Ground

The temperature range of the G1 extends lower than most traditional EGT systems to include temperatures normally encountered at start-up. Under normal engine operation at 1,000 to 1,200 rpm, the G1 will produce a white bar EGT indication for each cylinder. The precise indication will vary from one installation to another, and it is not unusual to observe fairly large EGT differentials between cylinders at idle or taxi power settings.

One very useful feature of the G1 is its ability to detect abnormal combustion during the pre-take-off run-up.
The primary purpose of the pre-take-off engine run-up is to verify the airworthiness of the engine's ignition system, plus carburetor heat and propeller control. Pilots without extensive engine instrumentation are accustomed to detecting engine and/ or ignition problems by an rpm drop or roughness during the run-up.

With the G1 a much more accurate diagnosis of problems is possible.

As you run your engine up to 1,700 or 1,800 rpm (or as recommended in your aircraft's Pilot's Operating Handbook), you will observe a rise in EGT for all cylinders, to about one third of full scale. Normally, these indications will vary somewhat from cylinder to cylinder. The G1 should be carefully observed during the magneto check.
Combustion is initiated by two spark plugs firing simultaneously in each cylinder.
Under single mag operation, only one plug is firing, producing only one flame front in the combustion chamber, resulting in a slower, more prolonged combustion.
This places the point of peak combustion pressure later in the power stroke and the tachometer will register a drop of 50 to 150 rpm. Since the exhaust gases have less time to cool before being expelled from the cylinder, the exhaust gas temperatures of all cylinders should rise. (50 to 100° F).

Various problems can be detected easily during run-up with the aid of the G1. The drop or EGT rise on single-mag operation indicates trouble in the form of a hot mag or defective ignition switch.
A more common indication of trouble is the total disappearance of an EGT indication for one or more cylinders after switching to single-mag operation, indicating a faulty ignition wire or spark plug. If the affected cylinder returns to a normal EGT indication when operating on the other magneto, you have isolated the problem to a single spark plug (or lead) in a single cylinder.

In the absence of adequate engine instrumentation, the initial diagnosis of fouled spark plugs is usually made on the basis of a greater rpm drop for one mag than the other. Manufacturers' handbooks generally warn the pilot to regard any difference of more than 50 rpm between mags as suspicious. But it is important to note that an rpm drop will register only if more plugs are fouling on one mag than on the other. If each magneto harness harbors one bad plug or lead this would cause a uniform mag drop and the double fault would go completely undetected. On the other hand, an entirely different malfunction such as a partially plugged injector could create the same symptoms.
Careful analysis of G1 can help a pilot determine the precise cause of mag drop, or pinpoint problems hidden behind a uniform mag drop. In both cases cited above, the G1 would indicate higher EGTs for the affected cylinders.

Run-up is also a good time to check carburetor heat (if present) and mixture control. Application of carburetor heat causes a reduction in the density (and therefore oxygen content by volume) of air coming into the engine, inducing an over-rich condition. This is indicated by a noticeable drop in engine rpm and exhaust gas temperature.
If the application of the carburetor heat control fails to produce these effects, it is likely that the carb heat control is misrigged, causing the airbox flapper valve to hang open and allowing hot air to leak into the carburetor on a full-time basis.

This should be remedied as soon as possible.

During the mixture check, a uniform rise of EGT indications for all cylinders will confirm that the mixture control is functioning correctly. The amount of temperature rise will depend on the degree of mixture control movement.
Each cylinder should show a rise in EGT upon leaning. Failure of a cylinder to show a significant rise, or an abnormally large EGT differential between cylinders in fuel injected engines, may indicate a fuel injector nozzle constriction.
In many engines, a large inter-cylinder EGT spread is normal at low power settings (even with fuel injection) so a diagnosis of this type is impractical until the pilot becomes thoroughly familiar with the normal indications for his or her engine.
Even so, this type of diagnosis, easily made with the G1, is virtually impossible with other EGT systems.

Using G1 On Take-off

The G1 can be used during takeoff to identify a very serious class of combustion problems that can result from poor fuel distribution at take-off power settings.

The combustion phenomenon known as pre-ignition can do extensive damage in a matter of a few seconds if left unattended. This combustion process produces abnormally high temperatures in the combustion chamber which results in immediate full-scale EGT indications followed by a rise in cylinder head temperatures.
Should this type of indication occur during the takeoff roll, the takeoff should be aborted.
If takeoff has proceeded beyond the point of no return, power should be reduced immediately (maintaining flight) and the mixture enriched if possible to make the temperature drop in the affected cylinder(s).
A precautionary landing should be made as soon feasible.
Pre-ignition can be caused by red-hot cylinder deposits or overheated exhaust valves.
Regardless of cause, pre-ignition, once started, causes an extreme temperature rise in the combustion chamber and is self-sustaining until engine failure occurs (often in a few seconds).
Broken connecting rods, melted pistons, and cylinder head separation are among the common pre-ignition induced failures.
A second type of pre-ignition that does not fit the previous definition is magneto induced pre-ignition.
It results from extreme timing errors in magneto adjustment or failure of the magneto itself.

Detonation in automobiles is commonly referred to as ping or knock. It is an unusually rapid form of combustion that follows ignition induced combustion and is caused by high compression, high temperatures and a lean mixture.
The rapid combustion of detonation is significantly advanced by the time the exhaust valve opens and the temperature encountered by the EGT probe is lower than normal. Detonation results in higher peak combustion temperatures and pressures which translate into higher CHT's and lower EGT's. More importantly, detonation imposes significantly greater stress on the engine components than normal operation. It may be caused by excessively lean operation at high power settings because of fuel system malfunctions, injector nozzle constrictions, improper mixture control settings, insufficient fuel octane or avgas contaminated by jet fuel.

Leaning for Take-off

Leaning normally aspirated engines for takeoff is advisable for best performance under high density altitude conditions and this is something that can be done with confidence and accuracy with the G1.
Remember that the full-throttle, full rich-mixture setting is designed to provide an enriched fuel flow for proper engine cooling during takeoff at sea level on a standard day.
This over-richness is a FAA-mandated minimum of 12% above the worst case detonation-onset fuel flow.

With increasing density altitude, this over-richness robs your engine of power. Leaning on a high altitude takeoff can restore a significant amount of power and add measurably to aircraft performance. Consult the Pilot's Operating Handbook for the airplane manufacturer's recommended high altitude takeoff procedures. On some aircraft equipped with fuel flow gauges, the full-power altitude reference marks indicate acceptable fuel flows for various altitudes (typical reference marks are S.L., 3000, 5000, 7000).

Sometimes a specific temperature (eg. 150° F rich of peak EGT) is specified as the takeoff power mixture guideline.

After some experience with the G1 to determine the location of peak EGT, the G1 can be used to set the mixture using this guideline, or (with careful operator technique) to produce the EGT indications similar to a normal sea level takeoff.

A New Approach to Engine Management

The G1 is a sophisticated tool for engine management. Its microprocessor performs many tasks that used to be handled by the pilot. One of the basic functions performed by the G1 is monitoring exhaust gas temperatures for all cylinders with one degree resolution. What is important is the exhaust gas temperature of a particular cylinder in relation to its peak.
But peak EGT is not a constant; it changes with atmospheric conditions, altitude, power setting and engine condition and for this reason absolute exhaust gas temperatures in degrees Fahrenheit are quite meaningless.

The real objective of mixture management is finding a mixture setting which represents the correct position on the EGT/Fuel Flow Curve. As we will see later, this abstract task is easily accomplished by the G1's microprocessor which samples EGT's for all cylinders many times a second and subjects this data to a complex mathematical analysis that can identify peak.
This capability allows the pilot to operate his or her aircraft engine at the most economical mixture settings.

It is generally known that EGT can be a valuable source of information for engine diagnosis and troubleshooting, but there is a great deal of confusion when it comes to interpreting this data.
One of the basic principles of EGT engine analysis is that engine temperatures (EGT and CHT) achieve equilibrium in an engine operating at a constant power and mixture setting.
What is often overlooked is that this equilibrium cannot be defined as a single point but rather a range of temperatures.

Fundamentals of EGT

The basic ingredients of combustion are fuel, air (oxygen), compression, ignition, and timing.
The measurement of Exhaust Gas Temperature (EGT) is really an indication of the harmony of interaction of these ingredients.
A slight change in any of these five factors will result in noticeable changes in EGT.

The measurement and dynamic analysis of these changes is a very valuable tool for engine management.
The use of exhaust gas temperature for mixture control depends on certain characteristics of combustion that are common to all engines. It is generally known that the exhaust gases get hotter as the mixture is leaned.
This temperature rise is a sign of increased combustion efficiency as the optimum mixture setting is approached.
If the leaning progresses past a certain point, the temperature will begin to drop. This temperature drop is the result of reduced energy output from the diminished fuel flow.

For a variety of reasons, the best operating mixture for aircraft engines is in the vicinity of this peak.
Some high performance engines require slightly more fuel for cooling and run best on the rich side of peak while others are designed for operation on the lean side of peak.
The shape and character of this curve is typical for all normally aspirated engines; it is, however, slightly affected by some turbocharger installations.

Principles of EGT Measurement

Exhaust Gas Temperature is measured with a temperature-sensing probe that penetrates the exhaust stack a few inches away from the cylinder. The sensing probe is made from a special alloy designed to provide long term protection for the temperature sensing elements inside. The temperature measurement is actually made with a thermocouple sensor.
A thermocouple is a welded junction of two alloys that generates a tiny voltage when heated.
The EGT probe uses Chromel (90% nickel, 10% chromium) and Alumel (95% nickel, 5% aluminum, silicon and manganese).
Only 22 millionths of a volt are generated per degree Fahrenheit. The G1 measures these tiny signals and translates them into temperature.
The EGT probes are designed to have a small thermal mass for fastest possible response, and the manufacturing procedures are tightly controlled to maintain probe calibration to within one degree.

Principles of CHT

Like EGT measurement, Cylinder Head Temperature (CHT) is also monitored by means of a thermocouple which generates a voltage proportional to its temperature. The G1 is designed to work with three different kinds of probes.
The gasket probe replaces one of the spark plug gaskets on a cylinder and is held in contact with the cylinder by the spark plug. The spring-loaded probe screws into the temperature well in the cylinder and its tip is pressed against the cylinder by spring pressure. The third kind of CHT probe is called an adapter probe. It screws into the temperature well, but unlike the spring-loaded type, it allows the factory installed bayonet probe to remain in place.
While the basic principles of CHT measurement are similar to that of EGT measurement, the range of temperatures is much lower; typically 500° F or less.

There are certain times when you should not lean to peak or even attempt to find peak. In full power climb or any time the engine is operating at power settings in excess of 75%, leaning to peak could result in detonation and serious engine damage. This is especially true for high performance engines and turbocharged aircraft.

Importance of Measuring Turbine Inlet Temperature

The measurement of TIT has become popular in recent years with some aircraft coming so equipped right from the factory. Although turbine inlet temperature is an invaluable operating parameter, a great deal of confusion still surrounds TIT indications and their meaning. Turbine inlet temperature is measured by a single probe mounted in the exhaust inlet to the turbocharger. The TIT display shows the temperature of the exhaust gases that drive the turbo.
In many cases this probe is just a foot or so downstream of all the EGT probes. At first glance this measurement appears redundant. Why read the temperature again when it is just the collection of all the EGTs?
TIT is not a simple function of the collective exhaust gas temperatures. It may be hotter than the hottest EGT that feeds it or cooler than the coolest EGT.
The temperature measured by the EGT probe is the average of the pulse of high temperature gases that exit the cylinder when the exhaust valve opens. The TIT probe sees the collection of pulses from all cylinders that feed it and will indicate a higher temperature.

Turbo action is throttled by the wastegate valve that forces a portion of the exhaust gases to bypass the turbo.
At low altitude, with little demand for turbo-charging, the wastegate will direct a large part of the exhaust past the turbo and the TIT probe will read a lower temperature. At higher altitudes the wastegate will close to direct more energy to the turbo and a higher TIT will be indicated.
TIT is not just a simple function of EGT and this is very important to consider when operating a turbocharged engine.
A power setting and fuel flow that may be well below peak EGT and well below the TIT redline temperature at 9000 ft may easily exceed the TIT redline at 16000 ft. The higher temperature results from more exhaust gas driving the turbo to restore the manifold pressure at the higher altitude.
The TIT reading is a key factor in leaning the turbocharged engine. It also provides diagnostic information that is unavailable from other sources. A wastegate system malfunction will affect TIT readings under conditions where other indications are normal. Should the wastegate stick closed at high altitude, all indications would appear normal.
Subsequent throttle power reductions for descent would show a deceptively normal decrease in manifold pressure but abnormally high TIT readings for that situation. Other factors such as ignition, fuel distribution, induction, or compression that affect EGT will also affect TIT; sometimes with detrimental results.
For example, ignition failures that cause the EGT to rise may increase the TIT past redline.

Special Considerations for Turbos

Turbocharged engines exhibit some special characteristics that result from the interaction of the turbocharger, throttle, wastegate controller, and other engine components. These interactions will vary in degree depending on the engine type and installation. In the normally aspirated engine, the components of combustion are essentially fixed for a given throttle and mixture setting. Any mixture control change results in a direct mixture change.
The turbo has one additional complication that results from mixture changes:
A change in mixture changes the exhaust gas energy that drives the turbo.
This change in turbo drive energy changes the induction or manifold pressure and temperature and may or may not be compensated for by the turbo wastegate controller.

The turbo also has significant inertia which causes a lag in response to changes in drive energy.
The result of this turbo bootstrapping is a change in the EGT/Fuel Flow Curve depending on the direction of mixture movement. This lag must be understood and taken into consideration to properly lean the engine.
This change in the curve becomes evident if the pilot tries to enrich the mixture to drop the temperature one bar.
In most turbocharged engines it will take considerably more fuel flow to drop the temperature one bar than it did to achieve that temperature on the way up. For example, in a normally aspirated engine, enriching for a 25 degree drop may take a 1/2 gph increase in fuel flow. The same model engine when turbocharged may require a 2-4 gph increase in fuel flow to get the same 25 degree drop. Paradoxically, the pilot may even see EGT rise when he starts enriching before it begins to fall.

Another observable characteristic is that the required fuel flow is dependent on altitude under conditions of constant rpm and manifold pressure. It may seem reasonable that the optimum mixture for a given power setting should remain constant. However, when the turbo compresses the induction air it also increases its temperature and reduces its density.

Although the manifold pressure is restored, the oxygen content of the induction air is reduced because it is a function of air density. It should be remembered that the exact nature of this complex and confusing issue is dependent on the engine and installation. For this reason it is difficult to make generalizations about the leaning characteristics of turbocharged engines, but one thing can be said with certainty: a generous enrichment of the mixture from peak will prolong the life of exhaust valves, the wastegate and the turbocharger itself.