OPERATION INSTRUCTIONS
FOR INSIGHT GEM 610C-001

DOCUMENT No. 070907

PLEASE READ INSTRUCTIONS COMPLETELY BEFORE PROCEEDING

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TABLE OF CONTENTS

Warranty and Service

The Insight Instrument Corp. 610C Graphic Engine Monitor system (G3) is warranted against defects in materials and workmanship for two years 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 G3 system, please read the G3's documentation. Every G3 system is shipped with complete instructions for installation and use. The answers to many technical questions can be found in this booklet, or the G3 Installation Manual. Insight provides customer support free of charge for as long as you own the instrument. If you have any questions concerning G3 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.

G3 Install Location Cautionary Notice

The G3 graphic engine monitor has EGT, CHT and TIT primary STC.
Mounting installation of the G3 should be in a clear and user friendly viewing location.

G3 display should be mounted within the pilot's subpanel or the center panel and not on the copilots subpanel unless the G3 can be canted towards the pilot.

G3 Fuel Totalizer Cautionary Notice

The Fuel Remaining display on the G3 is very useful but is not without limitations. Understand first that the factory fuel quantity gauges are the only instruments in the panel that physically measure fuel level. They are still the primary indication of fuel level in the airplane.

The G3 doesn't measure level, but instead measures only fuel flow rate. The G3 totalizes the rate information to account for fuel used. If you know how much fuel you started with and how much you have used you can figure fuel remaining by simple subtraction. The pilot must supply an accurate starting fuel level for this subtraction to produce the correct fuel remaining result. Should the pilot overstate the fuel quantity on board, the G3 will dangerously overstate the fuel remaining and the endurance time as well. The pilot must be careful and diligent when setting the fuel on board.

Getting the correct fuel total on board is in many cases pretty easy. If you fill up prior to takeoff the number is obviously the total available on board. If you partially fill a known configuration (say tips empty) then the total is easy to calculate. If you partially fill fuel tanks or add an accurately know quantity to a poorly known original value - errors will abound. Unaccounted fuel loss from leakage, fuel vent overflow or theft will of course produce erroneous results.

So be careful and the G3 will deliver safe, reliable, and convenient fuel information. But be sure to cross reference the information on the primary fuel quantity gauges. Never trust a single source of fuel information when you have two on board. Fuel exhaustion still ranks highly among accident causes. There is no excuse for this - don't let your engine stop until you're parked.

G3 Series

Introduction

Insight's 610C Graphic Engine Monitor (G3) colour-coded bargraph and digital values may be Primary for CHT and TIT.

All other data shown in cyan at the top of display are to be supplementary.

Traditional multi-cylinder exhaust gas and cylinder head temperature systems that force the pilot to switch or scan an indicator from cylinder to cylinder in search of critical engine data, are long obsolete. Using the latest computer technology, the G3 presents a clear, concise, graphic picture of all engine temperatures simultaneously for interpretation at a glance. Never before has so much engine diagnostic information been available to the pilot and never before, has the pilot been able to control mixture with such ease and precision for peak fuel efficiency.

Insight's latest G3 automatically records flight temperature and will also interface with other data sources and report information to other instruments like MFD’s. The data-log files stored on the SD card can be easily retrieved by the pilot, in-flight or post-flight, for instant viewing or permanent record-keeping.

A New Approach to Engine Management

The G3 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 G3 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 G3's microprocessor which samples EGT's for all cylinders many times a second and subjects this data to a complex mathematical analysis 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.

The 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 G3 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.

In fact, the G3 will help you monitor mixture, timing, fuel distribution, compression, oil consumption, and many other subtle engine phenomena. The G3 can actually resolve engine phenomena that occur in millionths of a second.

Principles of CHT

Like EGT measurement, Cylinder Head Temperature (CHT) is monitored by means of a thermocouple which generates a voltage proportional to its temperature. The G3 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 too 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.

G3 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 G3 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 mindset 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. But to make it even easier to operate at a certain predefined temperature difference a user settable threshold is provided. Reaching or exceeding this threshold is annunciated by the temperature box changing from hollow to solid filled. Precise leaning to a predetermined setting can be as simple as moving the mixture until all the boxes turn solid.

The Graphic Engine Monitor (G3) 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 G3 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.

Leaning in Cruise

The G3 is ready for leaning without any user action. 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. Temperatures preceded by an ‘L’ eg ‘L47’ are lean of peak while those prefixed with an ‘R’ are rich. In addition to the letter lean setting are displayed in white and rich setting in cyan. The user may set a threshold which is used to trigger the box from being hollow to being solid filled. Should the user wish to operate say 25 degrees lean he/she may set the threshold and lean until all the lean boxes are displayed as filled. This is a simple and easy way to lean correctly and precisely.

Restarting the leaning process

The use may restart the leaning process and reset the peak indications at any time by pushing and holding the bottom button for about 3 seconds until the indications disappear. The user should enrichen the mixture to the rich side of peak and lean from there.

Setting the threshold

The user may set the threshold anywhere from 0-99 by pushing the lower button twice and then turning the knob to set the desired number. When complete a short push of the bottom button will clear the threshold setting message.

First Flight with the G3

During the first flight with the G3 the pilot should enable EGT auto-ranging and set the inflection value to 800 on the user configuration screen. The instrument will calibrate itself for optimum operation. A the end of the flight the user should set EGT auto-range to ‘SAVE’ and set Save config to YES and push the lower button. This will save all configurable items in non-volatile memory and restore them to those saved values for each flight. Refer to the section on Setting Options for more detail on user configuration.

Using G3 on the Ground

The temperature range of the G3 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 G3 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 G3 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 G3, 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 G3 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 G3. The absence of an rpm 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 G3 data 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 G3 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 mis-rigged, 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 G3, is virtually impossible with other EGT systems.

Using the G3 on Takeoff

The G3 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 Takeoff

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 G3. 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 G3 to determine the location of peak EGT, the G3 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.

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 G3. 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 Leaning without Lean Mode

There are occasions when the pilot may wish to lean manually. It is informative on the first G3 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.

Lean 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.
The top row of indications show RPM, manifold pressure fuel flow, buss voltage, oil temperature and OAT.

The basic G3 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.

Set the lean threshold as described above.

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. To operate rich of peak, move the mixture control in the rich direction until the boxes show solid cyan with an 'R' number inside in black. To operate lean of peak, move the mixture control in the lean direction until the boxes show solid white with an 'L' number inside in black.

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:

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.

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.

The 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 wil prolong the life of exhaust valves, the wastegate and the turbocharger itself.*

Special Considerations for Twins

Some twin engine aircraft exhibit an unusual mixture control reversal characteristic. We speculatively attribute this to the long flexible cable used to link the cockpit controls with the engine. The phenomenon is easily observed in aircraft with fuel flow gauges. When the pilot pulls back on the mixture controls to lean the engines, fuel flow is reduced and the EGT rises as expected. But when the mixture controls are pushed forward to enrich the mixture, the fuel flow continues to drop and the EGT drops on the lean side of peak. Even though the mixture control is moved in the rich direction, leaning continues. It would appear that the function of the mixture control has temporarily reversed! Continued movement of the mixture control picks up the slack and normal mixture function resumes. The magnitude of this phenomenon varies from aircraft to aircraft, but we have observed transitions of up to 1.5 gph past peak before the fuel flow began to increase. Monitor the fuel flow gauge to identify this phenomenon in your G3

G3

Controlling the G3 instrument

The instrument has two control knobs that operate combination rotary and push button switches. The top knob in general controls screen selection while the bottom knob controls items within the given screen. Each screen assigns its own functional needs to the controls that may change depending on context. A screen may also label the controls with guidance information like “Push to exit”.

Some of the many revolutionary new features of the G3 system include:

Engine vibration measurement and analysis.
Specialized analysis for propeller balance, turbulence and even landing shock
Integrates, logs data from G3, TAS Air Data and GPS for the complete picture
SD Card stores all engine, air, winds aloft and fuel data (No more lost data)
Entire aircraft life history directly on SD card in PC compatible form
Specific functionality for safe Lean of Peak operation with no detonation
Oil Temperature and Pressure
Manifold Pressure, Fuel Flow and RPM
OAT
Carburetor and Alternator Temperature
Buss Voltage

G3 PAGES IN ORDER
STARTUP SCREEN

G3 MONITORING

The Bar-Graph DisplayScreen

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 G3 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.
The instrument may eventually accommodate engines with 4,6,7 or 9 cylinders in which case the appropriate number of columns will be displayed and numbered.

PROBE DIAGNOSTIC Screen

Troubleshooting avionics is an expensive and time-consuming process. Often times the procedure requires access to the instrument connector for continuity measurements. This might take hours of instrument panel disassembly just to touch the connector. We needed something better, easier to use, less time consuming and therefore less expensive. G3 measures the resistance of the temperature probe junction and each of its lead wires. You can tell if any wires are broken, chafing, or shorting and whether the probe is degrading or near failure. You can replace probes at your convince instead of waiting for them to fail. This will totally eliminate intermittent behavior caused by probe problems.

Periodic Temperature Variation Screen

This is a new form of engine analysis. Some valve related engine faults produce a slow periodic variation in EGT. The oscillation rate is on the order of one cycle every minute or two. This is just too slow to be identified by casual observation of the temperatures alone. Yet it is very important to discover this phenomenon because it may lead to a catastrophic engine failure. It readily appears in a slow sampled spectrum analysis. A normal indication will be a flat line with a little noise, while a trouble indication will show as an obvious spectral peak.

VIBRATION SPECTRUM
Engine Vibration Screen

Engine vibrations is reported by an engine mounted 3 axis accelerometer collocated with the fuel transducer. The typical display of spectrum data uses the horizontal axis as frequency. This is disadvantageous in this application because the displayed peaks would slide back and forth with changes in engine speed. Ideally the harmonic position on the graphic display should remain fixed regardless of engine speed to retain a familiar consistent picture. The sample rate of the accelerometers is phase locked to the engine speed so the number of vibration samples per engine revolution is constant. The FFT vibration harmonics remain stable with changes in engine speed. The horizontal axis is therefore not labeled in frequency but in multiples of engine speed. Three axes of vibration are displayed in a log magnitude harmonic form. in three different colors. The user may select the axis by push the top button. The base noise level is about 72 db below full scale. Multiple axes facilitate identification of the vibration source. The user may pan & zoom the vibration display to focus on any area of the display by pushing the bottom button and turning the bottom know. Engine vibration is a valuable tool for the detection of mechanical faults, and propeller balance measurement, but is also important for lean of peak operation where achieving an acceptable level of engine roughness is a goal. When the question is how much vibration is normal. The G3 provides the answer.

PROP BALANCE
Propeller Balance Screen

Propeller balance has a significant effect on engine smoothness. Just the slightest propeller imbalance has a profound affect on passenger comfort.

Typically props are balanced on the ground using helicopter balance equipment. The G3 uses the engine vibration accelerometer and the once per rev or once per 2-rev spark signal to derive prop balance values. Because the sample interval is phase locked to the prop rotation the FFT magnitude and phase of the fundamental harmonic is a good measure of prop balance. Not all of the fundamental harmonic vibration is attributable to the propeller but adjusting balance to minimize it, no matter what the cause, achieves the most comfortable result. The harmonic magnitude is a measure of the correction weight required and the harmonic phase indicates the clock angle of the correction weight location. The balance display shows phase as a polar vector like the hand of a clock and magnitude as a linear bar graph with a numeric reading.

Once a calibration value has been determined a second bar graph with numerical presentation displays the mass of the required correction weight directly.

A change in prop balance may indicate a propeller fault, blade damage, spinner damage, ice in the spinner, blade ice accumulation or ice shedding.

TAKE-OFF PERFORMANCE

2-AXIS G-LOAD
Turbulence Display

The G3 contains a 3-axis accelerometer sampled at modest rates to measure turbulence and landing shock. Knowledge of G forces will help the pilot to operate the airplane safely by slowing to maneuvering speed. Landing shock is a good training aid for smooth landings and a predictor of structural damage. Data logged G force will report unauthorized aerobatic activity or abuse of rental aircraft. It could also be useful in accident investigation.

Configuration screens

There are six configuration screens. The User config screen is the only one accessible by the pilot in flight. The Set Time/Date and registration screens are accessible on the ground. Other screens are accessible only by the dealer to configure the instrument at installation time.

GENERAL INFO
CONFIGURATION
REGISTRATION
ENGINE CONFIGURATION
CLOCK / CALENDER
USER CONFIGURATION

T.H.P.

Data-Logging

Introduction to Data-Logging

Files are created directly in CSV format (comma separated values) for direct importation in Excel
Logging of engine temperature data on a routine basis allows the creation of a complete engine-operation history, a detailed record documenting each hour of an engine's life.

Data-logging with the G3 provides the benefits of long-term trend monitoring through a standardized personal computer interface. The G3 data-log system makes it easy to retrieve log data from all flights.

The G3 automatically records parameters during every flight. Each flight's data is stored in an individual log file on the SD Card. Every file has an identification header containing the date, time, aircraft- registration and data log configuration. All data is sampled and recorded every one second of flight with essentially no limit as to size. Data acquired with the G3 can be viewed directly in raw form, or imported into spreadsheet and database programs for graphical analysis.