Gem 602
Single Engine - Normally Aspirated

Gem 603
Single Engine - Turbocharged

Gem 610
Single Engine - Normally Aspirated or Turbocharged with Data Logging

Gemini 1200
Twin Engine - Normally Aspirated or Turbocharged with Data Logging

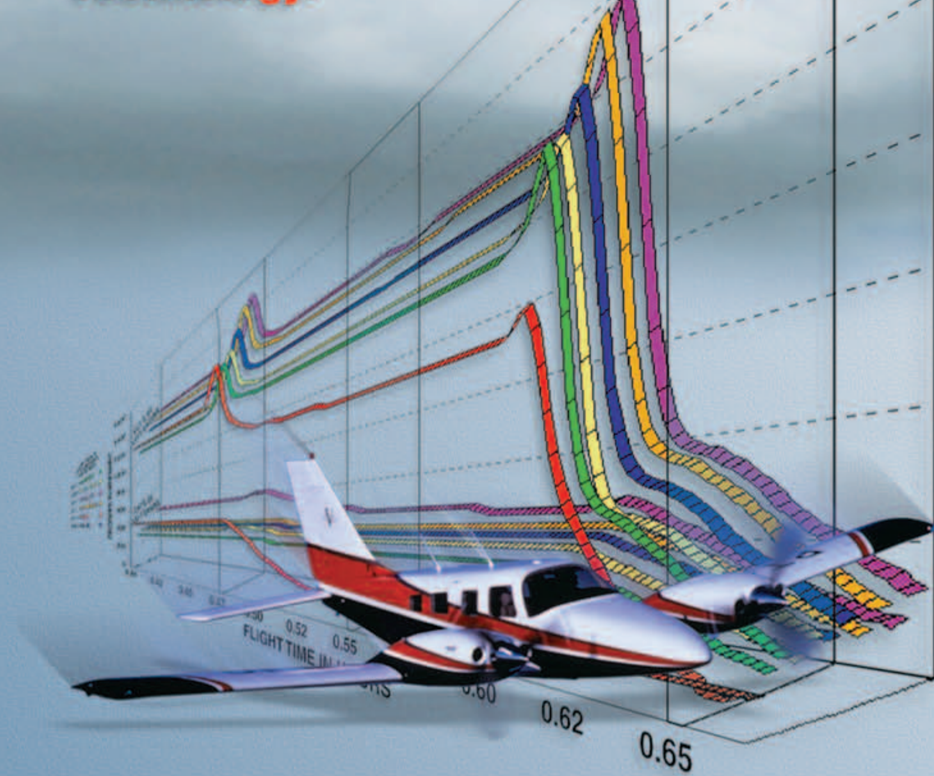
Pilot's Guide Graphic Engine Monitors

Pilot's Guide

Graphic Engine Monitor Data Logging System

Gem Series
602, 603, 610 and 1200

The Industry Leader in Engine Monitoring Technology.



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Instrument Corp. *Innovation on Display*
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Gem Series

Graphic Engine Monitors

Pilot's Guide

Models 602, 603, 610, and 1200.

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Insight Instrument Corp. Innovation on Display

Contents

Gem Series
Graphic Engine Monitors

The Insight Story

During the summer of 1981, a radical one-of-a-kind instrument appeared in a Bonanza's panel. Bright orange bars of gas plasma climbed the display, revealing the secrets of the engines every power stroke. At that instant the notion of engine monitoring one cylinder at a time was obsolete.

The world's first **Graphic Engine Monitor** (GEM) had been created. Its public unveiling at the 1981 American Bonanza Society convention triggered a demand for the revolutionary GEM. Insight Instrument Corporation started as a one man operation to manufacture the GEM 602, which rapidly became the new standard in engine monitors.

In 1983, Insight introduced the GEM 603. The ideal blend of digital and analog display formats, the 603 added a digital numeric display to the now-famous Insight bar graph.

In 1984, Insight began to produce all of its own temperature probes in house.

In 1986, Insight focused on creating a new technology, a digitally based airborne weather avoidance system. The basic principles of long-range storm detection had been public knowledge for several decades, but commercially available products for pilots were painfully expensive and outdated. The challenge was to utilize the latest computer technology to produce a reliable, accurate and light weight storm detection system at a price pilots could afford. After six long years, Insight Avionics Inc. delivered the world's first digital weather avoidance system, the **Strikefinder**, in May of 1991. Like the GEM before it, Strikefinder has set a new standard in the aviation world by offering quality and value at a very competitive price.

In 1992, response to relentless market demand, the Insight design team announced another avionics first. The GEMINI 1200 data-logging Graphic Engine Monitor, the world's first engine monitor specifically designed for twin-engine aircraft, raised standards once again. With its classic GEM look and feel, the GEMINI 1200 features a handheld computer with a wireless infra-red interface for programming and information retrieval. The computer and IR interface provide the essential link between engine information and the desk top computer.

The GEM 610 followed in 1993. Similar in appearance to the classic GEM 603 it includes all the same advanced features of the GEMINI system.

Strikefinder customers were the first to hear, (in 1994) of Insight's development of a self contained solid state heading stabilization system for Strikefinders. The gyro-less design installs in minutes and will never require adjustment or overhaul.

The GEM's and Strikefinder's reputation for performance and ease of use are no accident. The Insight design team includes experienced pilots, aircraft owners, programmers, and engineers with a thorough understanding of aircraft systems, technology, and the cockpit environment to craft instruments that are finely tuned to the needs of the pilot.

Insight's history of innovation and refinement is based on an endless cycle of research, development, manufacturing and quality testing. We work closely with our suppliers and customers to ensure the most efficient application of ideas and technologies to problem solving.

With each new design we advance the leading edge of technology, redefining state of the art. Graphic Engine Monitors and Strikefinders now protect pilots and passengers in thousands of aircraft around the world. Typically installed in high performance IFR equipped singles and twins, thousands of GEMs perform daily service in every type of aircraft. Although a relative newcomer in the avionics world, Strikefinders are now standard equipment for aircraft operated anywhere the sound of thunder may be heard.

Insight spends much of its income on research and innovation. The tremendous success of the GEM series of engine instruments funded the six year effort required to develop Strikefinder. The Strikefinder now supports continued research and develop of exciting new avionics systems.

Watch for Insight to bring even more innovation and value to the world of aviation.

GEM Series Pilot's Guide

Introduction

Insight's **Graphic Engine Monitors (GEM)** are the most advanced engine instruments available to the pilot. Traditional multicylinder 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 **GEM** presents a clear, concise, graphic picture of all cylinder 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 GEM automatically record flight temperature data in non-volatile memory. The data-log files can be easily retrieved by the pilot, in-flight or post-flight, for instant viewing or permanent record-keeping.

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. *Figure 1* is an actual temperature curve from an aircraft engine operating in flight at 75% power. Notice that the curve is quite round on top.

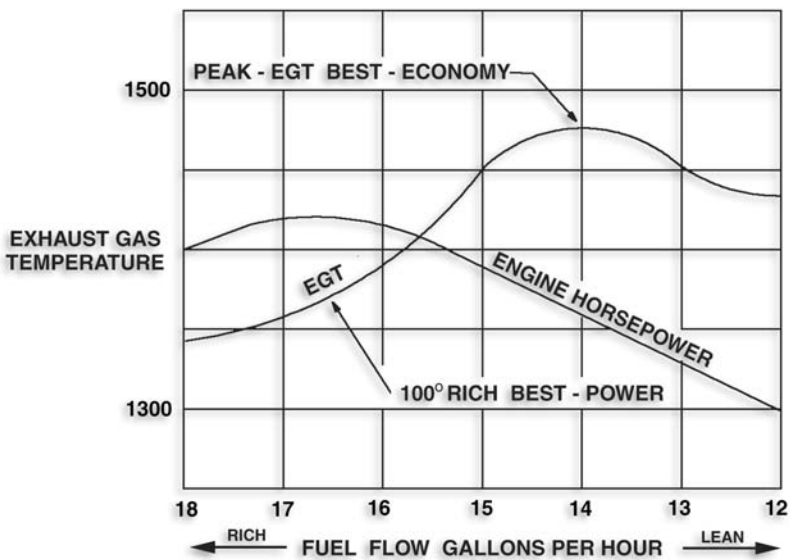

Figure 1 EGT/Fuel Flow Curve

This is true for all engines. 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, but for most, **peak EGT** is optimum. The shape and character of this curve is typical for all normally aspirated engines; it is, however, slightly affected by some **turbocharger** installations (*See Special Considerations for Turbos, p.27 for details*).

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 GEM 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**.**

Thermocouple sensors, an old and proven technology, are the heart of many industrial and aerospace measurement applications. In the GEM they are used for much more than just measuring temperature. That's why we say the GEM is *more than just a thermometer*.

In fact, the GEM will help you monitor mixture, timing, fuel distribution, compression, oil consumption, and many other subtle engine phenomena. The GEM 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 GEM 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.

Understanding the Display

The GEM is designed to display the exhaust gas and cylinder head temperatures of all cylinders simultaneously. The cylinders are numbered across the bottom of the display (1, 2, 3, 4, 5, 6). Four cylinder installations will have only 1, 2, 3 and 4 illuminated.

GEM 602, GEM 603

At the top of the display are *two* **annunciators**, EGT and CHT that identify the temperatures displayed by the bar-graph. The GEM-603 model for turbocharged engines also displays Turbine Inlet Temperature (TIT) in digital format. At the top of the GEM-603 display are *four* annunciators EGT, CHT, TIT and °F.

GEM 610, GEMINI 1200

The **GEM-610** and **GEMINI 1200** utilize an advanced feature set including EGT **trend indicators**, **Cylinder-number Highlight boxes**, and a high-resolution digital numeric display. (See the GEM 610 and GEMINI 1200 chapter for detailed description and operation information.)

The Bar-Graph Display

The Exhaust Gas Temperature is displayed in **bar graph** form and is interpreted much like a conventional mercury thermometer. The higher the bar, the higher the temperature. Reference marks for EGT are provided on the left side of the scale. These marks are not numbered because absolute temperatures are of no value for **mixture control**. The cylinder head temperature is displayed in negative single bar format. During normal operation it shows as an unilluminated bar in the lower half of the bar column. Calibrated reference marks (2,3,4,5) represent hundreds of degrees Fahrenheit and each column bar represents 25 degrees. The missing bar method of displaying two parameters on a single bar graph concentrated the information on the same display for easy comparison of each cylinder's EGT and CHT. Since EGT is normally higher than CHT, the dark bar which represents CHT is surrounded by illuminated bars and stands out clearly. However, when the engine is shutdown, the EGT quickly drops to zero and the cylinders remain warm for sometime. In this case, the CHT indicator reverts to an illuminated bar surrounded by a dark field. The GEM 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, but the CHT bar, instead of remaining black, will revert to a bright orange bar. The failure of one probe will not affect the display of any other probe.

The turbine inlet temperature on GEM-603 models is displayed numerically in tens of degrees Fahrenheit. For example, a display reading of 159 indicates TIT of 1590°F.

Modes of Operation

The Graphic Engine Monitor has three modes of operation:

- **Lean Mode**
- **Monitor Mode**

Lean Mode is used during cruise to identify the leanest cylinder. Lean Mode can be entered at any time by depressing the Reset Button for about two seconds, until the **EGT annunciator** in the upper left corner of the display begins to blink. In Lean Mode the GEM's microprocessor analyzes the EGT outputs of each cylinder's **thermocouple probe** to arrive at a determination of the **leanest cylinder**. The **lean cylinder** is then annunciated to the pilot by blinking the corresponding EGT display column. As explained further below, Lean Mode is used during final fine tuning of the mixture.

The GEM is in Lean Mode only when the **EGT annunciato**r is blinking. **Monitor Mode**, indicated by a steadily illuminated EGT annunciator, may be entered at any time by simply pushing the Reset Button momentarily. If the Reset Button is held too long, Lean Mode will be activated. Each time Monitor Mode is entered, any blinking columns will stop blinking, and current EGT readings (as registered with one degree accuracy by the GEM microprocessor) are automatically stored in computer memory for future reference. Should any cylinder's EGT subsequently rise 50°F or more, the corresponding column will begin blinking, to signify a change in **combustion**.

Test Mode initiates a hardware diagnostic routine intended to be used before engine start-up. To activate Test Mode, depress the Reset Button while the power to the instrument is turned off then switch on power to the instrument. As soon as the GEM starts its precisely programmed test pattern the button may be released. Starting with the display column for cylinder number one, orange bars will stack up until the full column is illuminated, then blank out; next column two will light up, and each column will proceed in succession. The test will terminate with column six. The GEM-603 TIT indicator will display 000 during the test. At the end of the test the bars will flash in a random pattern and on the GEM-603 the TIT indicator will display a random number while the microprocessor resets itself. If necessary, the test may be repeated by switching off instrument power and initiating the procedure again. It is not necessary, or even recommended, that the pilot invoke Test Mode at the outset of every flight. Test Mode is designed to be used if trouble with the GEM system is suspected.

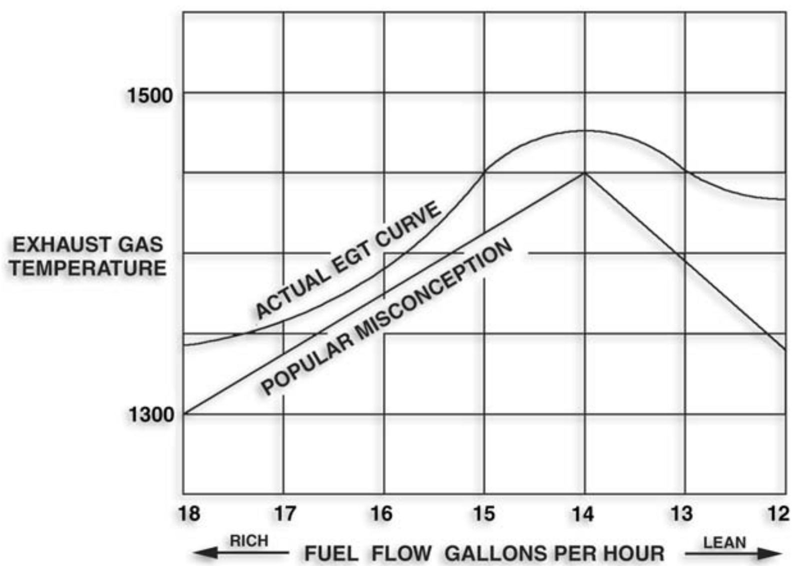

Figure 2 EGT Curves: Fact and Fiction

A New Approach to Engine Management

A great deal of misinformation exists concerning EGT measurement and its application to engine management. While the underlying principles have long been a matter of indisputable fact, many EGT 'myths' persist. Part of the problem is, that until the advent of the GEM, the technology did not exist to exploit the physics of EGT for the practical purposes of the pilot. The old, inadequate technology, it seems, fostered an inadequate and inaccurate understanding of the subject.

The GEM 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 GEM is monitoring exhaust gas temperatures for all cylinders with one degree accuracy. Some pilots ask why the GEM does not display EGT's on an absolute scale. The GEM does not display **absolute temperatures** because they are of no value for mixture management or engine troubleshooting. 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** (*see Figure 1, p.7*). As we will see later, this abstract task is easily accomplished by the GEM's microprocessor. The EGT curve is often depicted as rising to a sharp peak and then falling precipitously on the lean side (*see Figure 2, p.12*). But any pilot with experience using EGT for leaning can tell you this isn't true. In actual fact, as the engine approaches peak, it takes a proportionally larger change in **fuel flow** to effect a change in EGT. Finding **peak EGT** is not as easy as some would have us believe. In order to find peak reliably, one must monitor and compare EGTs for all cylinders throughout the leaning procedure. In fact, manual leaning to any degree of accuracy with a needle or digital readout is always problematical and often impossible. However, the GEM '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 much more accurately and reliably than even the most skilled user of a traditional EGT gauge. This capability allows the pilot to operate his or her aircraft engine at the most **economical mixture settings** without fear of the damage caused by over-leaning.

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.

In the real world, engine temperatures are affected by a number of variables (such as atmospheric conditions) and fluctuate constantly over a small range with little significance. It follows that one of the subsidiary tasks of engine analysis and troubleshooting is to separate the significant excursions from variations that fall within the normal temperature range. Three key design features of the GEM have made this job easier.

The first was the optimization of display resolution. The 25 degree increments of the GEM display serve as a **data filter.** Unlike numerical representations which display engine temperatures with one degree resolution and fluctuate constantly, the GEM display changes only when there is a significant alteration in engine equilibrium. Though some pilots insist that one degree display resolution is important to them, it serves no useful purpose in engine diagnostics, leaning or engine operation.

A second important design choice was the **bar graph display**. With a little experience, GEM users learn to relate the pattern of bars with what is normal for their engine. Any change in this pattern is perceived with a glance, and because of the display resolution, is indicative of a significant change in engine conditions.

The third key feature of the GEM addresses the problem of **detecting intermittent engine problems**. Often temporary excursions in EGT's are indicative of a serious impending problem. With traditional EGT systems it is impractical to detect this class of problems since it would require the constant attention of the pilot. The GEM, unlike passive temperature indicators, monitors EGT's for you and annunciates any rise of 50 degrees or more by blinking the appropriate column.

The GEM is a new approach to engine management made possible by the utilization of microprocessor technology. The GEM makes sophisticated in-flight engine analysis practical for the first time, and leaning accurate and reliable. Its carefully designed ergonomics make it the easiest to use of all engine monitoring instruments.

GEM Operating Procedure

The **Graphic Engine Monitor (GEM)** is ready to operate the moment electrical power is applied. Within seconds after starting the engine, orange bars stacked in 4 or 6 columns will begin to appear on the GEM display. Each column corresponds to the **Exhaust Gas Temperature (EGT)** of a cylinder. The lowest exhaust gas temperature that can be displayed by the GEM 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 dark (unilluminated) bar in each column. Until you shut down your engine at the end of the flight, the GEM will continue to indicate CHT and EGT and can be referred to at any time for leaning purposes, or to diagnose a possible **engine malfunction**.

First Flight with the GEM

During the first flight with the GEM the pilot should determine that the instrument is correctly **calibrated.** The GEM is calibrated at the factory for the average engine, but may require adjustment for some engines. Before your first flight familiarize yourself with the basic operating procedures outlined in this section. Establish a cruise altitude of five or six thousand feet and follow the steps outlined in *Leaning Using Lean Mode* *(p.22-23)* to adjust your mixture to ***peak EGT***. If your GEM is correctly calibrated and your engine is leaned to peak, the instrument(s) should resemble the photograph on the front or back cover. The highest bar(s) should be even with the **asterisk reference mark** and each column of bars should show one dark bar indicating CHT. If the highest bar is above or below the asterisk, the instrument requires **calibration**. After noting the position of the bars, complete the mixture adjustment procedure by enriching the mixture an appropriate amount. Should the instrument require calibration, this can be done in flight by a mechanic or on the ground. For GEM 602 or GEM 603, the mounting screws must be removed and the instrument backed out of the hole to gain access to the adjustment screw. Turn the screw clockwise to raise the bars and counter-clockwise to lower the bars.

For **GEM 610** or **GEMINI 1200** systems the palmtop computer is used to adjust the EGT column indication. *Please see the chapter on GEM 610 and GEMINI 1200 for details.*

Using GEM on the Ground

The temperature range of the GEM 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 GEM will produce a one or two 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 GEM is its ability to detect **abnormal combustion** during the **pretakeoff run-up**. The primary purpose of the **pretakeoff 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 GEM, 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 GEM 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 two to four bars (50 to 100°F).

Various problems can be detected easily during run-up with the aid of the GEM. The absence of an rpm drop or EGT rise on **single-mag operation** 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 GEM 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 GEM 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, but four bars or more would be typical before the onset of engine roughness from fuel starvation. 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 intercylinder 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 GEM, is virtually impossible with other EGT systems.

Using the GEM on Takeoff

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

The **combustion** phenomenon known as **preignition** 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 result 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. Preignition can be caused by red-hot cylinder deposits or overheated exhaust valves. Regardless of cause, preignition, once started, causes an extreme temperature rise in the combustion chamber and is self-sustaining until engine failure occurs (often in as little as 20 seconds). Broken connecting rods, melted pistons, and cylinder head separation are among the common **preignition** induced failures. A second type of preignition that does not fit the previous definition is magneto induced preignition. 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 GEM. 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 GEM to determine the location of peak EGT, the GEM 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 (4 to 6 bars below the asterisk reference mark).

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 GEM. 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 one bar, lean the mixture until the reading goes up, restoring the dropped bar. Repeat this procedure each time the EGT reading drops a bar due to ascent into less dense air to ensure that highest EGT is 4 to 6 bars below the **asterisk reference mark**. 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 GEM 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. The average of the bars should reach the **asterisk reference mark** before falling. If they do not, consult the **calibration** procedure in the *GEM Installation Instructions*. 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 a couple of bars 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 using Lean Mode

The basic GEM 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 EGT bars rise to a bar or two below the normal cruise indication, or until experience tells you the fuel flow is within a couple of gallons per hour of the anticipated final fuel flow.

- 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.

- Push and hold the GEM Reset Button for a second or two to enter Lean Mode. When you have entered Lean Mode, the **EGT annunciator** will begin blinking.

- Now slowly lean the mixture until one of the EGT columns blinks. This final leaning should take about five seconds. The blinking column of bars identifies the leanest cylinder (the first to reach peak EGT). The mixture may be slightly too lean depending upon how quickly the pilot has reacted to annunciation of **peak EGT**. Push the Reset Button briefly to stop the blinking.

- Enrich the mixture as desired. There are several ways of enriching the mixture. If the aircraft has a **fuel flow** indicator the pilot may elect to operate the engine at a fixed margin (eg. 1/2 gph) on the rich side of peak. Alternately, the pilot may choose to operate the engine at a fixed temperature drop on the rich side of peak. Enriching the mixture until EGT drops one bar will ensure that you are not on the lean side of peak and will establish a **best economy mixture setting** *(see Figure 1)*. To select the **best power setting the mixture** should be enriched further to drop the EGT three to four bars from **peak EGT** (75-100°F). If the engine and airframe manufacturer approve continuous operation at peak EGT for the current power setting and operating conditions the pilot may elect to not enrich at all.

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.

- If you have enriched the mixture after establishing peak EGT, push the Reset Button again to store this new exhaust gas temperature for **Monitor Mode**.

This procedure may not be applicable to all engines. In some aircraft the mixture may be dictated by other parameters: *see Leaning Restrictions*, *Leaning by Turbine Inlet Temperature*, and *Special Considerations for Turbos (p.24-27)*.

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. In lieu of specific manufacturer's recommendations, lean manually to obtain EGTs no higher than 6 bars below the **asterisk reference mark**.

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.

Figure 3. Cut-away view of compressor and turbine

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 turbocharging, 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.

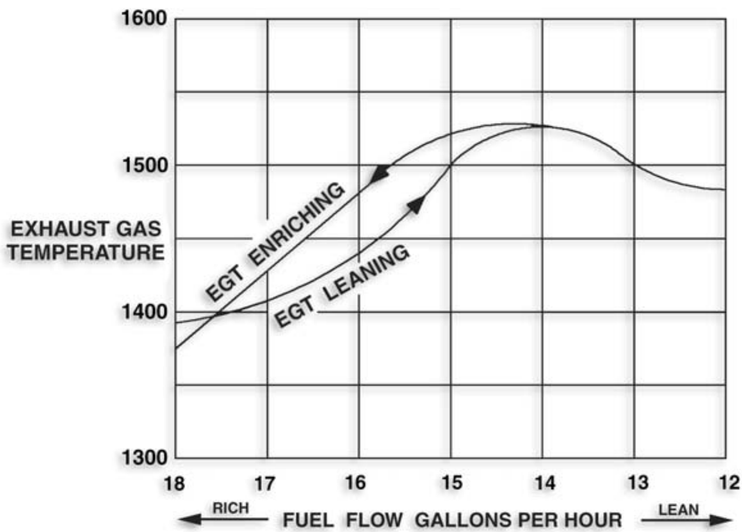

Figure 4. EGT/Fuel Flow for Turbos

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 (see *Figure 4,* p.26) 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*.

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

Figure 5. Piper Seneca V

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 aircraft.

GEM 610 & GEMINI 1200

Some of the many revolutionary new features of the **GEM 610** and the **GEMINI 1200** systems include:

- **Selectable Fahrenheit/Celsius Temperatures**
- **Normalize Mode**
- **Trend Indicators**
- **OAT and IAT Sensing**
- **Dual TIT Annunciators**
- **Soft Hobbs Meter/Clock/Calender**
- **Data Logging of Vital Engine Performance**
- **Software Configuration Programming**
- **Wireless Infrared Interface**
- **Hewlett-Packard HP Computer and Insight GEM Software**

NOTE: *HP refers to any of Hewlett-Packards HP95LX, HP100LX, or HP200LX Palmtop computers, all of which are compatible with the GEM 610 and/or the GEMINI 1200 series.*

THE GEM 610 Display

The GEM 610 displays 13 vital engine temperatures simultaneously. All Exhaust Gas Temperatures (EGT) and Cylinder Head Temperatures (CHT) are indicated by the **bar-graph display**, and any of EGT, CHT, Turbine Inlet Temperature (TIT) or Outside Air Temperature (OAT) can be shown by the 4-digit numeric display. All operating Modes of the GEM 610 are controlled by the display's SELECT and RESET buttons. Engine temperatures are automatically recorded in non-volatile memory within the display and can be transferred to an **Hewlett Packard (HP) Palmtop computer** in-flight or post-flight. (Non-volatile memory maintains storage without power.)

Figure 6. GEM 610 Display

THE GEMINI 1200 Display

Insight's trend-setting display format allows 26 vital engine temperatures to be easily assimilated by the pilot as part of the routine visual panel scan. The **GEMINI 1200** simultaneously displays all EGTs and CHTs in bar graph format, for both engines of a twin engine aircraft. Twin numeric digital-displays provide 4-digit read-out of any EGT, CHT, TIT, OAT or Inside Air Temperature (IAT). The GEMINI 1200 has a SELECT and a RESET button to control the operating modes for each engine's display. Engine temperatures are automatically recorded in non-volatile memory within the display and can be transferred to an HP computer in-flight or post-flight.

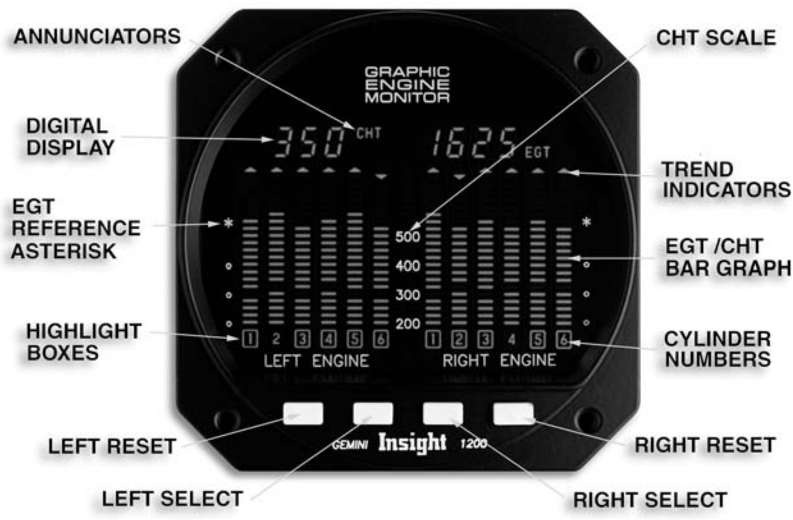

Figure 7. GEMINI 1200 Display

Interpreting the Bar-Graph

Cylinder Numbers identify each column at the bottom of the bar-graph display. Each number is surrounded by a "Highlight Box' annunciator.

The **Highlight Boxes** are used to indicate mode of display operation, and cylinder selection for the digital display.

Trend Indicators (Up and Down arrowheads atop each column) show the direction of the most recent change in EGT for each cylinder.

The Digital Numeric Display

The digital numeric display can show temperatures with four digits of precision and unprecedented accuracy. The temperature scale can be user set to Fahrenheit or Celsius.

Temperatures available for viewing on the numeric display are determined by the display's configuration. The GEM 610 and GEMINI 1200 are capable of digitally displaying the following temperatures for each engine:

- **EGT 1 through 6**
- **CHT 1 through 6**
- **TIT 1 and 2**
- **OAT/IAT (GEMINI) OR OAT (GEM 610)**

Note that the GEMINI 1200 has two digital displays, one for each engine. The data type selection is shown by the **annunciator** just to the right of the digital display (eg. EGT/CHT/TIT/OAT).

A software configuration feature is used to disable any unused inputs within the GEM 610 and GEMINI 1200. For example a normally aspirated 4 cylinder configuration for a GEM 610 would provide the following selections for digital display:

EGT 1 to 4, **CHT** 1 to 4, and **OAT**

A digital display indication higher than the working range (1800 Degrees Fahrenheit for EGT and TIT, 900 Degrees Fahrenheit for CHT) indicates fault in the wiring or probe for that indication.

TIT Priority

A GEM 610 or GEMINI 1200 configured for turbocharged aircraft have **TIT Priority** for the digital display. TIT will automatically be selected for display when the GEM is turned on.

Selection Memory

GEM 610s and GEMINI 1200s configured for normally-aspirated engines feature SELECTION MEMORY for the digital display. At start-up, the GEM will remember the last selection for each digital display. For example; if EGT cylinder five was shown on the digital display when the GEM was turned off, EGT cylinder five will automatically be selected for the digital display the next time the GEM is turned on.

Refer to Operating Procedures section for more information on using the digital display, p. 37.

HP Familiarization

The **Hewlett-Packard HP Palmtop Computer** is a powerful and important part of the GEM 610 and the GEMINI 1200 systems. The HP incorporating Insight's GEMCOM software is used to perform all of the advanced GEM functions such as CONFIGURATION and DATA TRANSFER.

Experienced DOS computer users will quickly become familiar with the HP, its built-in applications, and the infrared communication link. Less experienced users are strongly urged to spend some time with the "HP User's Guide". Everyone should read the "HP Quick Start Guide".

Figure 8. The HP Palmtop Computer

HPLX topics of interest:

1) HP Setup (Memory allocation, screen contrast, etc).
2) HP Power management (Battery types, AC adapters).
3) File management (FILER program or equivalent).
4) Data presentation (123 Spreadsheet progrom or equivalent).
5) RAM Cards
6) Data communications (File copy to other computers).

Introduction to Data-Logging

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 GEM 610 and GEMINI 1200 provides the benefits of long-term trend monitoring through a standardized personal computer interface. The GEM data-log system makes it easy to retrieve log data from all flights.

The GEM 610 and GEMINI 1200 automatically record parameters during every flight. Each flight's data is stored in an individual log file in non-volatile memory. Every file has an identification header containing the date, time, aircraft- registration and data log configuration. All temperatures are sampled and recorded every six seconds during flight (ten records per minute), and are encrypted using the proprietary **Insight-Compression-Algorithm (ICA).** ICA compression of flight data allows *up to 50 hours* of flight log to be stored on 32 Kilobytes of computer disk space. Encryption of the log ensures the integrity and security of the recorded flight data. *NOTE: Actual hourly capacity may vary widely depending on configuration, installation, operator technique, and many other variables*. GEMINI 1200 systems typically store 10 to 20 hours of flight time, GEM 610 systems 20 to 30 hours.

Data acquired with the GEM 610 or GEMINI 1200 can be viewed directly in raw form, or imported into spreadsheet and database programs for graphical analysis.

See the Data-Logging section for more information, p.58-60.

Operating Procedures

Flight Modes

The GEM 610 and GEMINI 1200 have three modes of operation:

- **Monitor Mode**
- **Normalize Mode**
- **Lean Mode**

A pilot will typically use **Monitor Mode** for ground operations and most phases of flight. **Lean Mode** may be selected to assist in adjusting **fuel flow** for cruise flight, while **Normalize Mode** may be used to detect un-commanded temperature changes during cruise flight.

Monitor Mode is the default power-on operating mode. All EGTs and CHTs are visible on the bar-graph, and the temperature currently displayed in the digital window is identified by the illuminated **annunciator** (EGT, CHT, TIT, OAT, IAT). The selected EGT or CHT cylinder number is indicated by the blanked cylinder **"Highlight Box"**. Momentarily push the SELECT button to advance the selection (2, 3, 4, etc.). Push and hold the SELECT button to reverse (4, 3, 2, etc.). Monitor Mode can be used in any phase of flight.

Normalize Mode allows easy observation of any change in EGT during cruise flight. Normalize Mode is entered by simultaneously pushing and holding both SELECT buttons on the GEMINI 1200 for two seconds. Push and hold the SELECT and RESET buttons on the GEM 610 for two seconds. The GEM will memorize the current EGT indications and electronically adjust the bar graph display to align all EGT columns with the "**Reference Asterisk**." Any significant change in an EGT results in obvious deviation from the "normalized" pattern. A single lighted "**Highlight Box**" will annunciate the cylinder number for EGT or CHT digital display during Normalize Mode operation. Monitor Mode may be re-entered by holding both SELECT buttons on the GEMINI 1200 for 2 seconds. Press and hold the SELECT and RESET buttons for two seconds on the GEM 610 to return. The pilot may switch between Monitor and Normalize Mode as desired.

Lean Mode is the computer-assisted GEM function which allows easy identification of peak EGT on the leanest cylinder. The function can be entered from Monitor or Normalize Modes. Lean Mode is entered by holding the RESET button for two seconds. The GEM will blink the current digital display annunciator (EGT, CHT, TIT, etc...) to indicate Lean Mode operation. Lean the mixture while watching the GEM. The leanest cylinder's EGT column will blink when peak EGT is reached. Momentarily depressing the RESET button will cancel the blinking column and exit Lean Mode.

Using the GEM 610 AND GEMINI 1200

The Digital Numeric Display

The GEM 610 and GEMINI 1200 displays will automatically perform a self-test each time they are powered-up. While the test is being performed (about two seconds), the software version number will be shown in the digital numeric display. Upon successful completion of the self-test, the digital display will revert to **Monitor Mode** operation. Failure of the self-test is indicated by the continuous display of the software version number in the digital numeric display (eg. "110"). In the event of failure of the self-test, the GEM will attempt to operate in "**Limp-home" mode**, showing only relative EGT indications on the **bar-graph display.** A failed GEM display should be serviced as soon as possible.

GEMs which are configured for **turbocharger** operation will default to TIT on the digital numeric display upon power-up. Normally aspirated configured GEMs will remember the last numeric EGT or CHT selection, indicated by the blanked-out **Highlight-Box** surrounding the cylinder number. Press the SELECT Button momentarily (see illustration of GEM displays, figures 6 & 7) to step forward through numeric EGT/CHT/TIT/OAT selections. Press and hold the SELECT button to step backwards (4, 3, 2, etc.)

Until the engine is shut down, the GEM will continuously indicate all CHTs and EGTs and can be referred to at any time for leaning purposes, or to diagnose a possible **engine malfunction**.

First Flight with the GEM 610 and GEMINI 1200

Prior to test-flying a new GEM installation, the system should be configured using GEMCOM on the **HP computer**. Complete system configuration may require adjustment of the following:

1) **GEM CLOCK** - Time and Date
2) **GEM CONFIGURATION** - Aircraft Registration and Probes
3) **EGT BAR HEIGHT** - Adjust as necessary.
4) **DATA-LOG CONFIGURATION** -Customize logging list.

   1) **GEM CLOCK** is factory-set to UTC (a.k.a. ZULU or GMT). Check and adjust if necessary.

   2) **GEM CONFIGURATION** is factory-set to enable all temperature channels. Modify the GEM's configuration to match the aircraft's installation (eg. 6 cylinder, 1 turbo, OAT). Enter the aircraft's registration number (tail number) at this time to allow identification of data-log files.

   3) **EGT BAR HEIGHT** must be observed during flight after the engine(s) have been leaned according to the aircraft manufacturers recommended procedure. Adjust the GEM's EG BAR HEIGHT to the EGT reference asterisk on the GEM's display.

   4) **DATA LOG CONFIGURATION** controls the data-log system and by default will mirror the GEM CONFIGURATION. The DATA-LOG CONFIGURATION will not normally require any adjustment.

Proper adjustment of the displays CONFIGURATION and EGT BAR HEIGHT functions are required for optimum performance of the GEM 610 and the GEMINI 1200. First generation Graphic Engine Monitors (GEM 602 and GEM 603) depended on internal hardware adjustment for GEM

CONFIGURATION (eg. 4/6 cylinders) and EGT BAR HEIGHT (formerly referred to as **calibration**). The GEM 610 and GEMINI 1200 Displays are factory programmed for typical engine configurations and parameters, but can be re-programmed using Insight's GEMCOM software program and an **HP computer**.

Configuration and testing of the data-log system should be performed to verify correct operation.

Pre-Flight

Note the configuration state of the GEM before flight and re-program if necessary. The GEM's configuration state should match the installed number of each type of temperature probe (Number of cylinders per engine, number of turbo-chargers per engine, OAT/IAT).

To determine the current configuration of the display, perform these actions:

1) Power-up and observe the GEM. If the GEM is configured for 4 cylinders, only cylinder numbers 1 to 4 will appear at the base of the bar-graph. Numbers 1 to 6 will appear if 6 cylinder configuration is selected. Use the SELECT button to step the **annunciators** (EGT, CHT, TIT, OAT/IAT) to determine if TIT(s) and OAT/IAT are enabled.

OR

2) Use the GEM CONFIG function of GEMCOM on the HP computer to interrogate the GEM display . Use the GEM CONFIG function of GEMCOM to adjust the GEM's configuration if necessary *(See the GEM CONFIG section, p.48).*

In-Flight

At the aircraft's normal cruise altitude, set power and mixture according to the aircraft manufacturers recommendations, and observe the height of the EGT bar-graph columns. The average EGT column should be even with the **Reference Asterisk** (*See Figure 6, pg.31 and Figure 7, pg.32*). Adjust the height of the EGT bar-graph display using the EGT BAR HEIGHT function of GEMCOM if necessary. Note that EGT BAR HEIGHT can be independently adjusted for each engine on the GEMINI 1200.

A missing EGT column or CHT bar indicates a fault in the wiring or probes for that cylinder. Note that columns five and six will not illuminate if four-cylinder mode has been selected during system configuration.

Post Flight

A data-log file can reveal important information about the condition of the GEM installation. Problems in the thermocouple probes, wiring harness, or GEM display will affect the data recorded in the data-log. A fault in the GEM's wiring harness or probes will result in a value of 32 Degrees Fahrenheit being stored in the data-log for the affected cylinder(s). After test-flying a GEM installation, cycle the electrical power to the GEM (to close the test-flight log-file) and transfer the test-flight log-file to the HP using FILE TRANSFER. Create an **ASCII** version of the log-file using the EXPAND FILE function of GEMCOM.

Quit GEMCOM and start the HPLX built-in spreadsheet program, and IMPORT the data-log file into a worksheet. Examine the file for correct ID header information and valid temperature data.

See the GEMCOM - INSIGHT'S Software for the HP, DATAANSFER and DATA-LOGGING sections for details, pgs. 44,51,58.

HP Palmtop Computer

Using the Computer

The **Flash card** supplied with your GEM system has been initialized and programmed with Insight's software program (GEMCOM). Insert the card into the slot and GEMCOM will be ready to run. Users wishing to use other computers or pre-owned **HP Palmtop Computers** must contact Insight Instrument Corporation for application information.

CAUTION: Any software or datafiles contained within your **HP Palmtop Computer** can be lost if you reinitialize the HP, or allow the main and the back-up batteries power to deteriorate. Files contained on the **RAMcard** are protected by the **RAMcard's** battery.

To prevent loss of the program:

1) The HP's batteries will gradually be consumed even when not in use. Use an external power adapter whenever possible to extend battery life, and/or replace the batteries often. Check the condition of the HP's main batteries using the built-in SETUP function [SHIFT][SETUP] on the HP95LX, [&...] then [SETUP] on the HP200LX.

2) Exit GEMCOM, and the "FILER" and "DATACOM" applications when they are not in use.

3) Remember to turn off the HP and remove the **RAMcard** when not in use.

Backup copies of GEMCOM software are available from Insight.

Questions specifically concerning the **HP Palmtop Computer** or any of its built-in software (DOS, FILER, DATACOM, etc.) should be directed to Hewlett-Packard. Telephone numbers are located at the back of the "HP Quick Start Guide".

Operating Hints for HP95LX Users

Use the HP's built-in FILER program to determine the amount of file storage space remaining on the HP. Run the FILER, press the MENU key, press "d" for directory and then "s" for status. The FILER will report various directory information including: "Bytes remaining on disk:".

File storage space may be increased by using the HP Setup function. Press [SHIFT][SETUP] and then press "s" for system.

The HP screen will display the current settings for speaker volume, screen contrast, and memory allocation. Setup allows you to increase the file storage area (RAM disk) at the expense of working memory (System RAM). Maintain a minimum of 300 Kbytes of System RAM if you intend to run LOTUS 123. See page 1-5 (Managing HP Memory) of the User's Guide.

RAM expansion cards are available from Insight.

The Infrared Communication Interface

Infrared (IR) data-communication technology is used to transfer information between the HP computer and the GEM 610 and GEMINI 1200. The IR communication link uses light instead of wires to convey information between devices. The HP computer has an IR communication port located on it's right side, adjacent to the wired communication port and the back-up battery. The GEM 610 and the GEMINI 1200 have IR ports built into their displays. To use the IR wireless interface, the HP's IR port must be within view of the GEM display.

Optimum position of the HP for communication with the GEM is 6 to 12 inches directly in front of the GEM display.

Some practice with the IR COMM TEST function of the GEMCOM software will demonstrate the best position and range. The GEM's display will exhibit a swimming effect during IR communication. This effect is normal and is a positive indication of IR activity. Consult the HP User's or Quick Start Guide for additional IR port information.

When to Download Flight Data

The ideal recommended time to download IDF and ADF flight files from the GEM 610 and GEMINI 1200 to the HP Palmtop is to turn Gem back on after engine shut down and avionics off.

Note: Starting in 1999 the infrared port on all GEM 610's and GEMINI 1200's models will be disabled during cruise flight.

GEMCOM - INSIGHT'S Software for the HP

The software program called "GEMCOM" was developed by **Insight Instrument Corporation** to provide remote control and data transfer functions between the GEM 610 and GEMINI 1200 displays and the HP.

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GEMCOM Compatibility

Only **HP Palmtop computers** bundled with GEM systems can be supported by **Insight Instrument Corporation**. GEMCOM was specifically designed for use with HP computers but will run on most computers that use DOS or a compatible operating system. Note that wireless data-communications with a GEM 610 or GEMINI 1200 require a Hewlett Packard Infra-red communications port. GEMCOM can be run on a desktop or other personal computer to EXPAND compressed data files from the archive form to ASCII format.

GEMCOM V2.00 for use on P.C's. with Pentium® II processors is now available.

Instructions for data logging and software downloads can be found on our website at **www.insightavionics.com**

Using GEMCOM

Automatic Start of GEMCOM:

GEMCOM can be launched automatically at any time by simultaneously depressing the CTRL, ALT, and DEL keys. Access to the HP BUILT-IN APPLICATIONS" can be gained by quitting the GEMCOM program (select Q from the GEMCOM Main Menu). This method of starting GEMCOM is facilitated by DOS's AUTOEXEC.BAT feature.

Caution: Depressing the CTRL+ ALT+ DEL keys reboots the computer and may result in loss of data if performed while running other application programs.

Hint: Save any data files and exit all applications before rebooting. Altering or deleting the AUTOEXEC.BAT or CONFIG.SYS file will disable this automatic start feature.

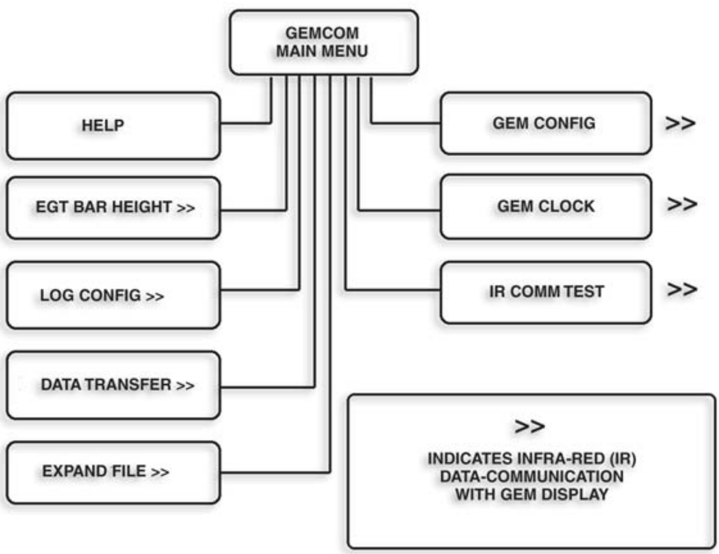


Figure 9. GEMCOM's Function Menu Structure

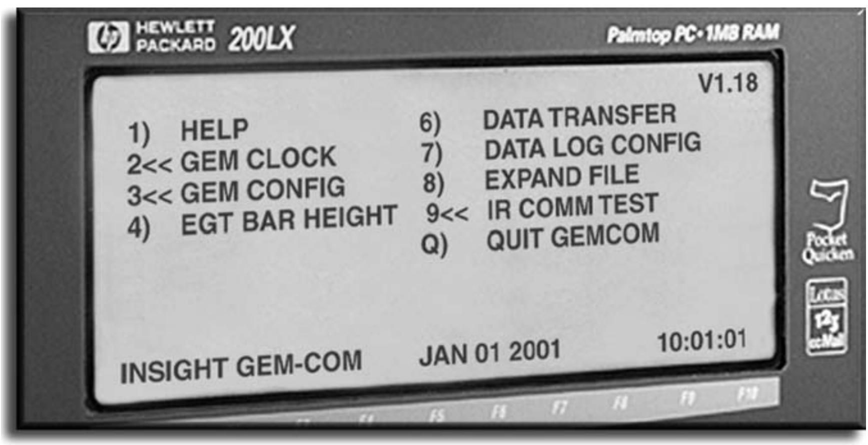
Manual Start of GEMCOM:

GEMCOM can be manually started from within the FILER by highlighting the "GEMCOM.EXE" file, and pressing ENTER. Selecting "Q" from the GEMCOM Main Menu returns control to the FILER.

Selecting Functions:

GEMCOM provides access to all functions through a standard screen menu system. Functions are selected by pushing the Number Key corresponding to the desired selection ("1", "2", etc. NOT the "F1", "F2" function key). Menu functions that perform Infra-red communications are indicated by a double arrow symbol after their menu number, eg. "2>> GEM CLOCK". Other functions provide a sub-menu of options, eg. "4) EGT BAR HEIGHT".

GEMCOM's MAIN MENU SCREEN:



1) HELP!

On-line help provides a brief overview of each function. First press the F1 key for the help prompt, then press the number key for the subject you want information on. The help messages are contained in a file named "gemhelp". This file must be in the same directory as the main program ("GEMCOM.EXE") for the help feature to work.

2>> GEM CLOCK

GEM CLOCK is the GEM 610's and GEMINI 1200's on-board internal clock/ calendar. Logged data is time/date stamped according to the GEM CLOCK time and date. The GEM CLOCK is factory set to UTC (a.k.a. ZULU or GMT) but can be set to any desired time.

The HP clock and calender is the master clock in the GEM system. To change the time or date on the HP use the built-in SETUP function:

1) Quit GEMCOM and press [SHIFT] [SETUP].

2) For time, press "t" for time, then "c" for current, and type the new time at the prompt and press [ENTER].

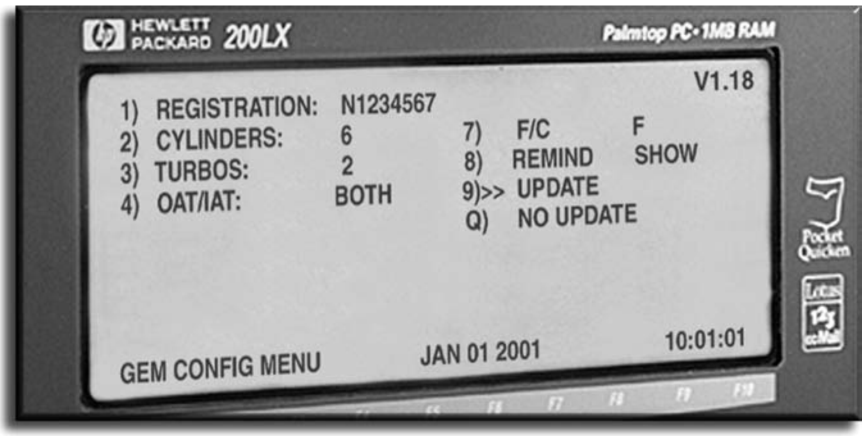
3) For date, press "d" for date, then c for current, and type the new date at the prompt and press [ENTER].

To access the GEM's internal clock, perform the following actions:

1) Run GEMCOM on the HP. Point the HP at the GEM 610 or the GEMINI 1200 display and select GEM CLOCK (press "2"). The HP will interrogate the GEM for its current date and time.

2) The HP will display the GEM CLOCK time and the HP time, and offer to reset the GEM's internal clock to match the current HP time. Depressing "Y" or "y" causes the HP to synchronize the internal clock of the GEM to that of the HP. Depressing "N" or "n" aborts the process and returns to the Main Menu.

3) GEM CONFIG



Characteristics of the GEM 610 and the GEMINI 1200 Displays are controlled by the GEM CONFIGURATION. The GEM CONFIG function reads and updates the GEMs configuration status.

Configuration options include: Aircraft Registration, Number of cylinders per engine, Number of turbochargers per engine, OAT and IAT probes, and Fahrenheit or Celsius temperature scales for the digital display. When enabled, the REMINDER will flash an "F" for Fahrenheit or a "C" for Celsius whenever the digital numeric selection is changed.

To check or change the configuration of a GEM 610 or GEMINI 1200 perform the following actions:

1) From GEMCOM's main menu, point the HP and select GEM CONFIG (press "3") to read the current display configuration. The HP will get the current configuration data from the GEM and display it on the GEM CONFIG MENU.

2) If required, modify the configuration shown on the HP to match the actual installation:

    1) Enter aircraft's registration number.

    2) Enter 4 or 6 for number of cylinders.

    3) Enter number of turbos.

    4) Enter "O" for OAT only, "I" for IAT only, "BOTH" or "NONE".

    6) Not implemented.

    7) Select "F" for Fahrenheit or "C" for Celsius scales.

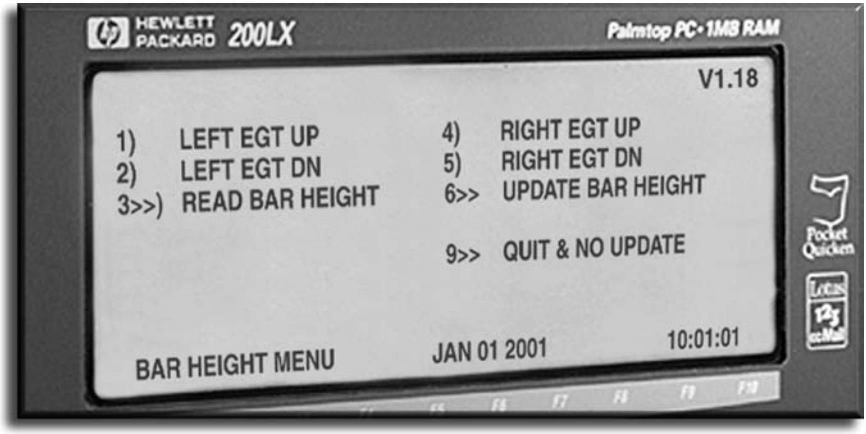
3) Point the HP again and select the UPDATE CONFIG (press 9") option to reprogram the GEM display. If no change to the configuration is required, press "q" to return to the MAIN MENU.

4) Repeat action No. 1 if desired to confirm the new display configuration.

4) EGT BAR HEIGHT

Indicated EGT values vary between engines dependant on specific location of the EGT probes. The GEM **bar-graph display** works best when the highest EGT column is even with the **Reference Asterisk** at normal power and mixture settings in cruise flight. *(See Figure 6 & 7, Pg. 31,32)* The EGT BAR HEIGHT function allows adjustment of the GEM's EGT bar-graph height. Adjustment of the EGT BAR HEIGHT may be performed in-flight or post-flight, based on observations.

4) EGT BAR HEIGHT



To adjust bar height perform the following actions:

1) From the main menu, press "4", the EGT BAR HEIGHT function sub-menu will appear.

2) Point the HP at the GEM and select READ BAR HEIGHT (Press "3"). The HP's message line will report the current EGT BAR HEIGHT setting(s) as a number of bars up or down (from nominal).

3) Change the bar-graph height settings on the HP's message line by selecting EGT UP or EGT DN as required.

4) Point the HP at the GEM and select UPDATE BAR HEIGHT.

5) Repeat steps 1 to 4 to re-adjust or confirm new setting.

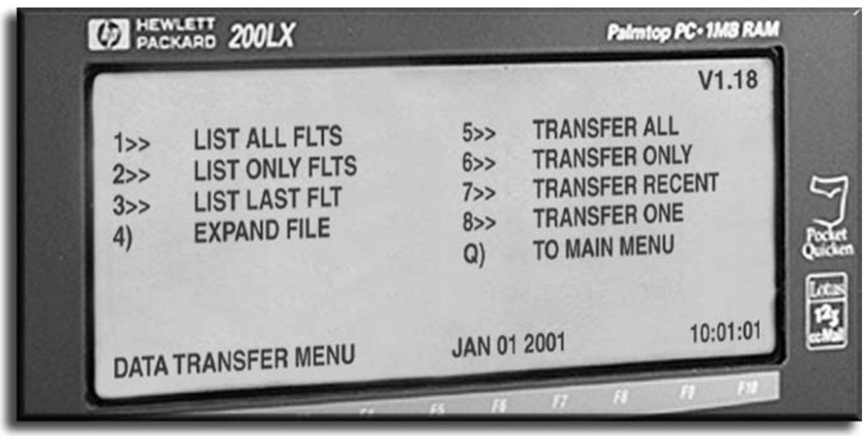
6) DATA TRANSFER

Software version 1.1X features advanced data-logging, data-transfer and file management capabilities. During flight, the GEM samples all temperatures specified in the data-log configuration and records temperature changes at six second intervals (ten records per minute). **Data-logging** automatically begins at instrument power-up and continues until shut-down. Data-log files can be transferred from the GEM to the HP at any time.

NOTE: Intensive IR communications require near-full main batteries (AA size), or the use of an external power adapter to avoid draining the HP's batteries during use.

The DATA TRANSFER functions allow the user to get a list of log files contained within the GEM, and then transfer a single file or group of files.

8) LIST FUNCTIONS:



1>> LIST ALL FLTS - lists all log files contained in the GEM's data-log memory.

2>>LIST ONLY FLTS - lists only those flights that have not yet been transferred from the GEM to the HP.

3>>LIST LAST FLT - lists the current log file in the GEM.

4) EXPAND FILE - not really a TRANSFER function, but a shortcut to the EXPAND FILE menu. Data files transferred from the GEM to the HP are encrypted in IDF or ADF format. The EXPAND FILE functions will convert the encrypted files to ASCII format for immediate viewing or further processing. See the DATA FILES section for more information on file formats.

NOTE: A minus sign preceding a file name in a listing of data files indicates that the file has already been transferred to the HP. The transfer function does NOT erase the original data-file from the GEM's memory and the file may be transferred again.

TRANSFER FUNCTIONS:

The transfer functions will copy data files from the GEM to the HP. If a group transfer (TRANSFER ALL or TRANSFER ONLY) is performed, an ADF file will appear in the HP in the current subdirectory. If a single flight is transferred (TRANSFER ONE or TRANSFER LAST), an IDF file will appear. The default subdirectory for GEMCOM is "C:\GEM".

Data is transferred across the IR link at rate of 125 bytes per second. A data file (IDF or ADF) of 1000 bytes will take eight seconds to transfer from the GEM to the HP.

Note that IDF and ADF files need to be EXPANDED to **ASCII** format before the data can be viewed.

5>> TRANSFER ALL - transfers all the log files contained in the GEM's log memory. If the GEM's memory is full, this transfer could take up to four minutes to complete.

6>>TRANSFER ONLY - transfers only those log files that have never yet been transferred.

7>>TRANSFER RECENT - transfers the most recent flight file.

8>>TRANSFER ONE - transfers a single file chosen from a group list. The time required to transfer a single log file is dependant on the length of the flight data file. A short file will only take a few seconds to transfer. Specify the file by it's flight number shown by the LIST function.

To transfer data-log files from the GEM to the HP, perform the following actions:

1) Point the HP at the GEM and get a list of the available file(s)using the appropriate LIST function.

2) Point the HP again and transfer the selected file(s) using the appropriate TRANSFER function.

NOTE: Transferring a file from the GEM to the HP does not erase the original file from the GEM's non-volatile memory.

A copy of the data-file is created in the HP. The original data-file in the GEM's memory will exist until over-written by new data.

7) DATA LOG CONFIG

The DATA-LOG CONFIG controls which temperatures are recorded during the data-log process. The DATA-LOG CONFIG will by default mirror the GEM CONFIGURATION but can be modified by turning-off unwanted channels.

To check or modify the DATA LOG CONFIGURATION perform the following actions:

1) From the GEMCOM MAIN MENU, select DATA LOG CONFIG (press "7") and then point the HP at the GEM and press [ENTER] to read the current logging configuration.

2) The current logging configuration will be displayed on the HP. Use the cursor keys to move the blinking underline cursor to the item to be modified, and press [DEL] to toggle the item's status on or off. When turned-off, an item will be shown as an "X" on the menu.

3) Point the HP at the GEM and select UPDATE (press "1") to transfer the new logging configuration into the GEM, or press "q" to return to the main menu without changing the GEM.

When to use DATA LOG CONFIG

The main purpose of Logging-Configuration is to allow the selective exclusion of data from the logging process.

Some users may wish to maximize data log hour capacity by excluding unwanted data from the logging process. For example, excluding all EGT data and logging only CHT and TIT would increase log capacity by a factor of several times (CHTs tend to be more stable than EGTs due to the cylinder head's relatively large mass and long thermal time-constant.)

Electrical noise from malfunctioning engine accessories (eg. ignition system or battery charging system), may affect the GEM's temperature measurements. Typical symptoms of electrical interference include jittering temperature indications on the GEM's display. To prevent a noisy temperature channel from consuming data-log capacity, temporarily exclude the affected item(s) from the LOG CONFIG until repairs can be performed.

*NOTE: GEM's sensitivity to electrical noise may alert you to impending electrical or **ignition system problems** before they become obvious or even detectable by other instrumentation. **Do not ignore unusual or erratic indications!***

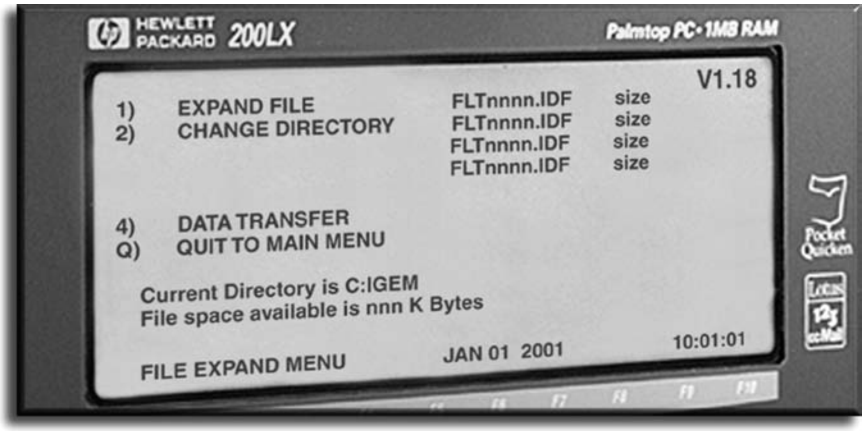
8) EXPAND FILE MENU

The EXPAND FILE function will decompress IDF or ADF format files that have been transferred from the GEM to the HP, and create the **ASCII** file required for viewing or analysis. Note that the ASCII file created by the EXPAND FILE function may be as much as 100 times larger in size than the original compressed IDF or ADF data file. Sufficient file storage space must be available on the computer disk for a new file to be successfully created.

Each minute of flight time will require approximately 1000 bytes of file storage space for the expanded ASCII file. Allow about 60 kilo-bytes of storage space for each flight-hour.

See the DATA LOGGING and DATA FILES section for more information.

8) Expand Functions:



1) **EXPAND FILE** - expands the highlighted file and creates a new file in ASCII format. The new file(s) will have the same name as the original but with an ASC instead of IDF or ADF. Use the cursor keys to move the highlight bar up and down the file list. If more files exist than will fit in the viewing window, the list will scroll as required.

2) **CHANGE DIRECTORY** - allows you to select a different subdirectory as the source of files for expansion. Useful for managing files from more than one aircraft.

Q) Return to **MAIN MENU.**

9> IR COMM TEST

The **IR COMM TEST** allows testing of the HP and the GEM 610 and the GEMINI 1200 wireless infrared communications interface. To test the IR link perform these actions:

1) Select IR COMM TEST (press "9") and point the HP at the GEM. The optimum position of the HP is six to twelve inches squarely in front of the GEM. The GEMCOM status message will indicate when the IR link is connecting. Audible "beeping" of the HP indicates successful IR communications.

2) Press ESC to terminate the IR COMM TEST and return to the main menu.

Note that sustained use of the IR link, such as when running the IR COMM TEST function draws heavily on the HP's internal batteries. Don't forget to press [ESC] to terminate IR testing when done.

Q) QUIT

QUIT exits GEMCOM and returns control of the HP to the operating system.

Data-Logging

The GEM's Data-Log System

The GEM automatically opens a new data-log file each time power is applied to the display. A data-log file consists of an identification (ID) header followed by the encrypted temperature data. The ID header contains the Aircraft Registration, log file serial number, starting date and time, flight duration, temperature scale, and data-log configuration.

Logging is controlled by the DATA LOG CONFIGURATION. The log configuration defaults to mirror the display configuration but can be modified using the DATA LOG CONFIG function of GEMCOM.

Switching the GEM off and then restarting it during flight will cause it to close the current data file and open a new one. Changing the GEM CONFIG or the DATA LOG CONFIG will reboot the GEM, causing the old data-log file to be closed, and a new one to open.

The data compression system is most effective on long cross-country flights with stabilized temperatures. Short flights with frequent temperature changes will fill the GEM's data-log memory more quickly.

It is important to transfer log data to the computer periodically. When data-log memory is full, new data files will overwrite and destroy the oldest data, files that have not been transferred are permanently lost. At any given time the GEM will contain the log files from the most recent flight(s).

Data Files

The GEM data-log system uses three different types of files to manage logged data: **Individual Data Files (IDF)** , **Archive Data Files (ADF)**, and **ASCII data files (ASC**). The IDF and ADF files are much smaller in size than corresponding ASCII files. Smaller files can be transferred in less time and require less disk space for storage.

1) **Individual Data File (IDF)** - contains an identification header (ID header) and the encrypted data from a single flight. Each IDF file is named after the flights log serial number. Example: 'FLT7.IDF". IDF is the native file format for the GEM logging system.

2) **Archive Data File (ADF)** - contains two or more IDF files, and a FLIGHT INDEX listing the contained IDF files. Each ADF file is named after the lowest flight-serial-number that it contains. Example: "FLT001.ADF" could contain the IDF files from flights 1, 2, and 3.

3) **ASCII data file (ASC**) - contains the ID header and data from an IDF file, but with the data expanded to ASCII format. ASCII is the American Standard Code for Information Interchange. The ASCII data format has the advantages of being readable and widely compatible with most types of computers, but at the expense of file size.

For example: "FLT123.ASC" would contain the same information as "FLT123.IDF", but the **ASCII** version of the file could be as much as 100 times larger in size.

The small size of the IDF and ADF files make them ideal for transfer and storage of data, ASCII files can be viewed directly on the HP's FILER, or IMPORTED into a spreadsheet program.

*See the **USING THE HP** and **DATA TRANSFER** sections for details on ransferring files from the GEM to the HP, pg. 51.*

Viewing Data Files

The **ASCII** data files created by GEMCOM's EXPAND FILE function can be viewed directly on the HP, but can benefit greatly from the larger screen and more powerful features usually provided by a desktop or comparable personal computer.

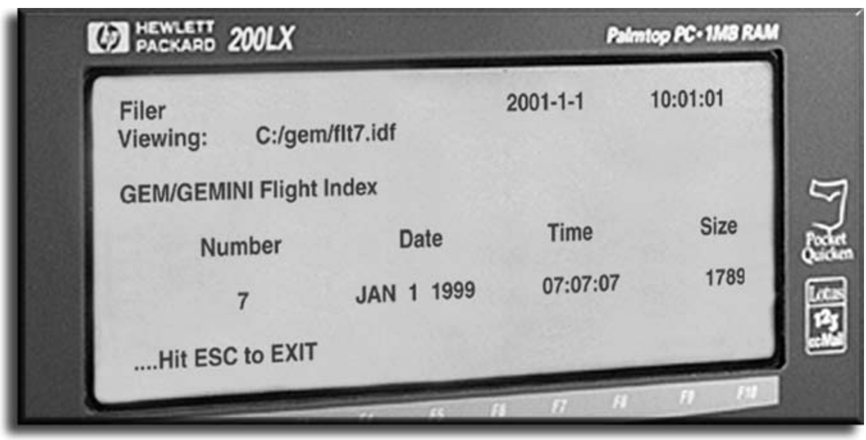
Viewing Data Files on the HP:

Use the built-in FILER program on the HP to view the contents of any log-files ID header.

To view a file on the **HP95LX**; run the FILER, use the cursor keys to highlight the filename to be viewed and press [ENTER].

To view a file on the **HP200LX**; run the FILER, use the cursor keys to highlight the filename to be viewed and press [F8].

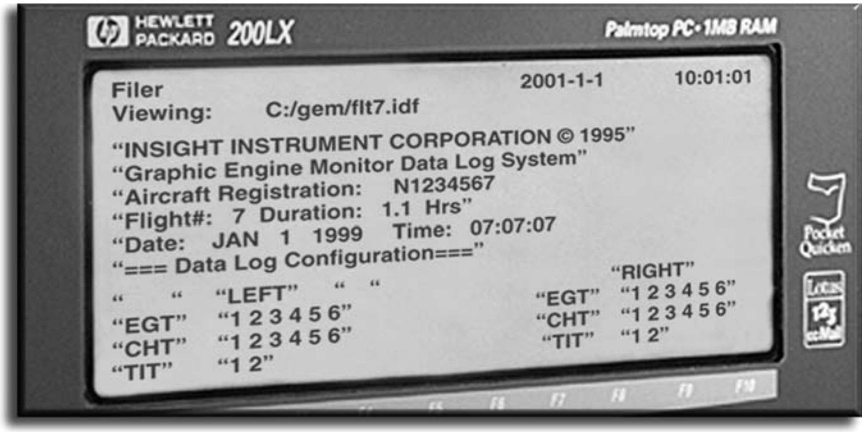
ID HEADER of an IDF file viewed by the FILER:



Note that the data area of an IDF format file will appear as random **ASCII** characters due to the data-compression.

The EXPANDED (ASCII format) version of a data file can be viewed directly with FILER, the HP's cursor keys allow the view to be scrolled through the file.

ID HEADER of an ASC file viewed by the FILER:



Viewing Data Using a Spreadsheet:

An EXPANDED (ASC) version data file can be copied into a 123 spreadsheet on the HP. To run the spreadsheet program, quit GEMCOM and press the [123] button. To copy the data file into the spreadsheet, perform the following sequence of keypresses:

[MENU], "f", "i", "n".

Type the full name of the data file including the directory, ex. "GEM\flt123.asc", [ENTER].
Please consult the HP User's Guide for details on using the FILER, *123,* and any other HP built-in application.

Viewing Data on a Desktop PC

Desktop or comparable computer offers many advantages for viewing and working with data-log files. The **ASCII** format (EXPANDED version) GEM data file is compatible with most computers and application programs.

Copying files from the HP to other computers requires the use of a Connectivity Package. This consists of an interconnection cable, and data communications software. The cable is used to connect the data-communication ports of the HP and the other computer. The communications software controls the transfer of data between the computers.

Spreadsheet programs are readily available for virtually every make and type of computer. Most spreadsheet programs provide the features needed to manipulate data files, including graphical functions.

A File Management Strategy

Consult the Notes section, pg. 63, for information on sources of computer accessories including data-communications and spreadsheet products.
Periodically, (depending on how often the airplane flys) transfer all the new data files from the GEM to the HP using the TRANSFER ONLY function. This will generate an ADF format file in the HP containing only the flights that have never before been transferred.

Using a serial interconnection cable and data-communication software, copy the ADF files from the HP to a desktop or full-screen portable computer.

Back-up the ADF files onto **Flash cards** or floppy-disks for safe-keeping.

Expand the ADF files to **ASCII** format for routine viewing and analysis. Delete the ASCII versions after viewing. They can be recreated from the archive IDF or ADF files if required for future review.
Keep the ADF files for efficient long-term storage of the data.

To reduce the risk of losing any data-files in the GEM before they are over-written by new data, transfer data from the GEM to the HP after every flight.

Notes for 610 and 1200 users:

1) HP accessories may be obtained from YOUR ONE-STOP PALMTOP SHOP (800) 709 9494.

2) Flash cards with copies of GEMCOM software are available from Insight Instrument Corporation.

3) GEMCOM V2.00 for use on P.C's. with Pentium® ll processors is now available.

4) Instructions for data logging and software downloads can be found on our website at **www.strikefinder.com**

5) Starting in 1999 the infrared port on all GEM 610's and GEMINI 1200's models will be disabled during cruise flight.

Diagnosing Engine Problems **with GEM**

The following are **engine problems** that can be readily diagnosed by interpretation of the **Graphic Engine Monitor (GEM)**. Frequently the same symptom may result from different engine faults. In some instances, with the aid of the GEM, it is possible to pinpoint the exact cause even while airborne. You may also experience changes in engine performance (reduced power, roughness, etc.) simultaneously with the GEM's annunciation of a problem. Due to the GEM's unique ability to display both **Exhaust Gas Temperature (EGT)** and **Cylinder Head Temperature (CHT)** for all cylinders at once, it is usually apparent which cylinder is responsible for the malfunction. This pinpoints the problem for the mechanic and facilitates making the necessary repairs.

Determination of a problem depends upon your knowledge of the engine. As you accumulate flying time with the instrument, you will observe and recognize the pattern of bars that is normal for different phases of flight. When the pattern is not normal you will have reason to investigate. The GEM can assist in finding a malfunction before it becomes serious.

Generally, the symptoms described in this diagnostic guide will occur in cruise. Finding engine problems during start-up is covered under *Using GEM on the Ground, p.17*.

1. GEM shows: a gradual or sudden rise in EGT of one cylinder. When temperatures are 50°F above normal the display will blink to warn you of the rise in temperature.

Probable cause: A) A **fouled** or defective **spark plug** or ignition wire. A plug with a cracked insulator may misfire at high altitude but function normally on the ground.

What to do: Switching to left and right mags momentarily will determine which plug or lead is at fault. Switching off the good plug will cause the EGT in affected cylinder to drop while all others will rise. A **fouled plug** may clear itself when mags are switched.

Probable cause: B) A reduction in the fuel supply to one cylinder. A partially plugged injector will cause EGT to rise. A leak in the fuel supply tube between the fuel distributor and injector will have the same effect. A completely plugged injector or fuel supply will result in no combustion.

What to do: Switching mags will cause EGTs to rise in all cylinders. There will be no drop in temperature as with the **fouled plug**.

2. GEM shows: above normal CHT in one or more cylinders.

Probable cause: A) Broken ring(s) will cause higher CHT because of additional cylinder wall friction.

What to do: Perform a **compression test**. Low compression with leaks past the rings will indicate ring problems. Leaky valves will tend to mask the problem. Depending upon the location and number of breaks, the effect on a compression test will vary.

Probable cause: B) Misplaced or damaged engine cooling baffles can adversely affect the direction of cooling air to certain cylinders. The temperature may vary with aircraft altitude and phase of flight (climb, cruise, descent).

What to do: Open cowl flaps and reduce power. If the temperature is dangerously high, cool the engine with enriched **fuel flow** and land as soon as possible.

Probable cause: C) Obstruction in the cooling system such as a bird's nest under the cowling. High CHTs resulting from this problem may be apparent during run-up or taxi.

What to do: Inspect under the cowling and remove any obstructions.

3. GEM shows: high CHT readings on one side of the engine (cylinders 1, 3 and 5, or 2, 4 and 6).

Probable cause: A) Restricted cooling air for one side of engine caused by either a **misaligned cowl flap** or restriction at the air intake. On some aircraft one inch of cowl flap misalignment will cause a 50°F difference in CHT.

4. GEM shows: all EGTs rise uniformly and the entire display blinks.

Probable cause: A) One magneto has failed with only one **spark plug** firing in each cylinder. The temperatures rise uniformly in all cylinders.

What to do: Check to make sure the mag switch is correctly positioned. Do not switch to **single mag operation** in flight (unless you want a total power loss). Enrich the mixture to reduce EGT. Land as soon as possible.

5. GEM shows: abnormally low EGT in one cylinder. (Two or more bars lower than the normal indication for your engine).

Probable cause: A) An **exhaust leak** between probe and cylinder, a cracked pipe, a loose or warped flange or a blown gasket.

Probable cause: B) An **intake valve is not opening** completely, resulting in a partial change of the fuel-air mixture, and consequently a lower combustion temperature.

Probable cause: C) An intake or exhaust valve is not closing completely, a burned valve, or poor compression. Reduced compression results in a lower combustion temperature.

Probable cause: D) In **turbocharged,** fuel injected engines an induction leak will enrich the mixture and cause a drop in EGT.

What to do: Perform the appropriate tests and inspections.

6. GEM shows: less uniform EGTs (most visible at cruise power settings).

Probable cause: A) Dirty injection nozzles. Fuel nozzles may accumulate residue which will restrict **fuel flow** slightly. The resultant rise in EGT is usually one or two bars in several cylinders.

What to do: Clean fuel nozzles. Regular service will prevent recurrences.

Probable cause: B) Induction system leaks, bad seals or bad gaskets.

What to do: Inspect and repair the induction system as required.

7. GEM shows: high CHT on one or more cylinders under all conditions after engine overhaul.

Probable cause: One aircraft owner discovered a piston connecting rod of the wrong type (too long) installed during an engine overhaul. This increased the compression ratio for this cylinder and caused the high CHT. Suspect this unusual problem only as a last resort.

8. GEM shows: all columns move up and down rapidly several bars. The action is random and can be described as *bars dancing up* and *down*.

Probable cause: A faulty ignition system, harness, ground or magneto. GEM will pick up an impending ignition harness failure before it is serious enough to materially affect engine performance. This may also be caused by a loose, dislocated, or damaged spark plug cap or a fault within the magneto.

What to do: Run-up the engine and check operation on each magneto. If the symptoms diminish or change on one mag then the problem is conclusively ignition related. This type of interference can frequently be heard on a Com radio with the squelch open or on the ADF. It is not only an indication of impending engine problems, but will reduce Com, Nav, ADF, and Loran performance.

The GEM will frequently identify problems in an ignition harness that tests OK on a high tension lead tester.

What to do: If the problem shows on only one mag then replace that harness otherwise replace both.

9. GEM shows: extremely high CHT reading on one or more cylinders.

Probable cause: Exhaust leak at flange which causes hot exhaust gases to strike the CHT probe.

What to do: Look for a blown exhaust gasket, a loose or cracked exhaust manifold, or a loose or missing exhaust manifold stud.

10. GEMINI shows: Left engine normal, right engine has a slight drop in EGT and rising CHT indications in one or more cylinders possibly accompanied by engine roughness.

Probable cause: Detonation.

What to do: Reduce power and enrich the mixture.On the ground, Inspect the cylinders for signs of **detonation**, look for fuel contamination, clogged injectors, or timing problems.

11. GEM shows: Extremely high or full scale EGT indications followed by high CHTs in one or more cylinders.

Probable cause: Preignition. What to do: Reduce power and land as soon as possible. Inspect the cylinder for damage.

12. GEM shows: An increase or decrease in EGT for all cylinders, especially after engine maintenance.

Probable cause: Retarded timing will increase EGT and advanced timing will decrease EGT. Note that cold, dense air with its higher oxygen content produces more power and higher EGT.

13. GEM shows: a drop in EGT for all cylinders in carbureted engines.

Probable cause: If accompanied by a drop in **manifold pressure** in aircraft with constant speed props (or a drop in rpm for aircraft with fixed pitch props) this is an indication of carburetor ice.

14. GEMINI shows: Black CHT bar missing in one or more columns on the left engine, entire EGT columns missing on the right (CHT bar automatically reverses color to remain visible).

Probable cause: Thermocouple probes may eventually fail after many thermal cycles. Loose or dirty connections in the wiring harness between the probes and the display may have the same symptoms.

What to do: Inspect and test probes and wiring harness, continuity test will reveal burnt-out probes. Burnt probes may appear good at low temperatures but fail when hot. Performing a run-up after swapping suspected faulty probes with known good ones is the most reliable test.

Questions and Answers on the GEM and Engine Operation

In this section we answer the most common questions we receive from pilots during our seminars and from phone inquiries.

Why does the GEM use a bar graph for EGT and CHT?

Ergonomics are an important part of instrument design. Insight pioneered the use of the gas-plasma bar graph for displaying EGT and CHT because of it's ideal suitability for this application. The graphical format displays all the data simultaneously in a way that's easy for the pilot to read and understand. Remember that Insight's 25 degree per bar resolution acts as a **data filter** to display only significant changes in temperature.

Why a digital display for TIT?

Many **turbochargers** are limited to a maximum inlet temperature of 1650 degrees Fahrenheit. Exceeding that temperature may result in catastrophic failure of the turbocharger and other parts of your airplane. The GEM prominently displays this critical temperature in it's most logical position, at the top of the bar-graph.

When I lean my engine the leanest cylinder is not the hottest. Sometimes the leanest is the coolest cylinder. Is there something wrong?

There is no correlation between the cylinder with the highest temperature and the one with the leanest mixture. In fact, a static temperature display conveys no mixture information whatsoever. Many pilots confuse the true meaning of the term **peak EGT**. Peak EGT is the highest temperature that a cylinder will reach when leaned under normal conditions. The first cylinder to reach its own peak during the leaning procedure is the leanest. Other cylinders may be hotter or cooler at that time, but none is leaner.

The GEM's microprocessor identifies the **leanest cylinder** by simultaneously analyzing the changes in temperature and the rates of change in temperature in all the cylinders during leaning. It is not confused by the absolute temperature of any cylinders. This dynamic analysis is the only practical means to derive correct mixture information.

My EGT indications are not very uniform at low power settings. Is this normal?

At idle and taxi power settings, poor EGT uniformity is characteristic of most engines. The low **manifold pressure** and low **fuel flows** at idle result in disparities in fuel mixture among cylinders that are not generally considered significant or troublesome.

My EGT indications are not very uniform at cruise power settings when the engine is leaned for normal cruise. Is the instrument at fault or is it my engine?

The GEM depends on a multiplexed measurement technique that assures identical **calibration** for all channels of the instrument. Since the same circuit measures each cylinder, temperature differences among cylinders cannot be related to instrument calibration. They may be related to temperature probe placement. It is important that each **EGT probe** be installed a uniform distance from the cylinder. The exhaust gases cool as they expand and travel down the exhaust stack, so the farther down the temperature probes are mounted, the cooler the indication. We recommend a mounting position tolerance of .062 inches. For some aircraft the positioning must be compromised because of bends, obstructions or baffles.

The most likely causes of poor EGT uniformity are engine related. If your engine has good compression, reasonable oil consumption in all cylinders, and no ignition faults, then uniformity problems are generally mixture related. In fuel injected engines, a one or two bar difference is considered reasonable. The most likely problem with an injected engine is dirty fuel nozzles. All injectors need routine cleaning with 100 hours being a typical interval. **Nozzle clogging** is not necessarily related to fuel contamination nor can it be stopped by fuel filters. It is a gradual accumulation of deposits that are left when fuel evaporates after the engine is shut down. These deposits are not very soluble in fuel so they accumulate over a period of time. In many engines this gradual constriction of **fuel flow** happens at a different rate for each cylinder resulting in mixture imbalances. Routine nozzle cleaning should be in the maintenance schedule of all fuel injected engines. This procedure generally takes an hour or less with most normally aspirated engines and sometimes a little longer for turbos.

Another problem is a mismatch of the **nozzle flow ratings**. Generally each nozzle has a letter or number that identifies its flow rating. Some times during overhaul or maintenance these nozzles may get interchanged with ones that look identical and may even have identical part numbers, but have different flow characteristics. While most engines should be equipped with injector nozzles of the same flow rating, some might benefit from nozzle mismatch to tune the flow to match the induction system, but that's another story.

Carbureted engines generally do not achieve as uniform a fuel distribution as an injected engine. The fuel-air mixture, after leaving the carb, must travel down various lengths of induction system tubing to the cylinder. Some of the fuel will have an easier path than the rest. **Fuel flow** in the induction system is also affected by the throttle position and carb heat controls, which create turbulence that may even be desirable to even out the fuel distribution to some extent.

Uniform fuel distribution is important to the smooth operation of any engine, but a perfectly uniform EGT display is no indication of perfection. Some degree of mixture imbalance is inherent in any type of engine.

How does the instrument handle a probe failure? Will it give erroneous indications?

The GEM continuously checks for faults in the entire measurement system and will instantly detect a faulty or marginal temperature probe or lead wire. Should a **CHT probe** fail, the black bar will disappear from the display and the EGT column will remain unaffected. When an **EGT probe** fails, the corresponding EGT column will read full scale and then go blank. The CHT display will revert to a bright bar and remain fully functional. The failure of one probe will not affect the readings from the other cylinders. However, the failure of any EGT probe will affect **Lean Mode** and reliable leaning indications will be unlikely.

Can any engine be operated at peak at normal cruise power settings?

No. Engine manufacturers differ in their approval of operation at peak EGT. In general, **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. Other restrictions apply to some special engines and to some special conditions. Consult your *Pilot's Operating Handbook* or engine handbook for specific details.

Is it important to use Test Mode before every flight?

No. **Test Mode** is intended as a diagnostic aid when a problem with the GEM system is suspected. It is unnecessary to use it routinely. If Test Mode is used, be sure to power down the instrument to exit Test Mode before starting the engine.

Does the GEM require any routine maintenance or calibration?

The GEM continuously checks and maintains its own **calibration** as part of the routine tasks performed by the microprocessor. Unlike other instruments, the GEM will remain in perfect calibration year after year without any adjustment.

What should I do when I detect a rise in EGT for one cylinder and the corresponding column blinks in flight?

The most common cause of a temperature rise is an ignition fault such as a fouled or internally cracked plug or an ignition harness wire breakdown. Switching mags in the air will pinpoint ignition problems, but is is not without some risk. If the fault happened to be a total mag failure then switching mags would cause total engine failure! Not a good way to impress your passengers and the sudden power stoppage might harm your engine. Some might say that even the rough running with one bad plug will harm your engine, or promote crankcase cracks. Some engine manufacturers have recommended that the mags be left alone while in flight. Switching mags in the air to diagnose problems should be done with extreme caution, but it is a fine technique for ground run-up tests. When you switch to the magneto connected to the bad plug, you will halt combustion to that cylinder and the EGT indication will drop rapidly and the engine will run rough. When that happens you have found the problem.

Why does EGT rise when a spark plug, ignition wire or magneto fails? With a lack of ignition, shouldn't it drop?

The combustion in a cylinder is designed to be initiated by both **spark plugs**. The flame front travels from each plug and the **combustion** process is largely complete by the time the exhaust valve opens. From the instant of combustion, the temperature in the cylinder rises rapidly to about 4000°F. The expanding combustion gases push the piston toward the bottom of its stroke and the combustion gases cool in the process. By the time the exhaust valve has opened and the piston has risen to expel the combustion gases, the temperature read by the **EGT probe** is about 1500°F. Since the EGT probe samples the temperature at the completion of the **combustion** cycle when the exhaust valve opens, any phenomenon that affects the timing relationship between the initiation of combustion and the opening of the exhaust valve will show as a change in exhaust gas temperature. Combustion initiated by a single plug is not as complete or as cool when the exhaust valve opens, so the EGT indicates 75-100°F higher.

Why does EGT drop during detonation. Shouldn't it rise?

Detonation is an abnormally rapid form of **combustion** that follows ignition induced combustion. It occurs under conditions of high compression and temperature and overly lean mixture. By the time the exhaust valve opens, the rapid combustion of detonation is significantly more advanced than normal, resulting in lower EGT and higher CHT indications.

I was taught to not lean until reaching cruise altitude, and never before 5000 ft. Is this correct?

Many pilots who routinely lean for high altitude takeoffs don't lean in the climb phase of flight. The fact remains that for normally aspirated engines higher altitudes effectively enrich the mixture whether you are in the air or on the ground. **Leaning during climb** is a recommended procedure for normally aspirated engines; it will improve performance and save fuel. Failing to lean in climb will **foul plugs**, create carbon deposits in the cylinders and make it harder to lean accurately at cruise altitude. A rule of thumb like this prohibition against leaning at low altitudes may make sense from an instructor's point of view on training flights, but it shouldn't apply to the experienced pilot seeking peak performance.

Why does EGT drop on the lean side of peak?

This phenomenon is commonly and incorrectly attributed to the cooling effect of excess air. In actual fact, the lower temperatures are the result of less fuel being admitted to the cylinder at leaner mixture settings. Less fuel means that less heat will be produced, resulting in lower temperatures.

I have read that EGT probe response time affects measurement accuracy. Is this true?

Several misstatements, based on a confused understanding of the thermodynamics involved, have been published on this subject. The accuracy of temperature measurement is unrelated to probe response time. However, probe response time severely limits the utility of unsophisticated gauge systems in finding **peak EGT**. All temperature probes, regardless of type or design respond to temperature changes exponentially. This means that a probe responds quickly at first and then more slowly as it approaches equilibrium with the heat source. For example, a probe exposed to a hundred degree temperature differential would indicate a 63 degree temperature change in a certain length of time, but would take five times as long to indicate the next 36 degrees. As might be expected, the nature of this response curve has serious implications when thermocouple probes are used to identify peak EGT for leaning. The GEM was designed with this in mind. Instead of merely measuring temperatures, the GEM's microprocessor calculates the first and second derivatives of the temperature data and thus entirely eliminates probe response characteristics from the peak EGT equation. The main factors in probe response time are thermal mass and exposed area. Most non-microprocessor based systems use small thin walled EGT probes sacrificing durability for faster probe response, while others have compromised on response time with thicker more durable probes. The design of the GEM yields both instantaneous response and probe durability.

Questions on the GEM 610 and GEMINI 1200

The **GEM 610** and **GEMINI 1200** have some advanced features not found in the GEM 602 and GEM 603. Following are frequently asked questions about the GEM 610 and GEMINI 1200.

When should I use NORMALIZE MODE?

NORMALIZE MODE temporarily equalizes all EGT indications on the GEM's bar graph. A subsequent change in any EGT will be immediately apparent against the "normalized" background. Be advised that NORMALIZE MODE can mask a developing problem by hiding the actual differences between cylinders. Press and hold the RESET and SELECT buttons for two seconds on the GEM 610 to toggle between MONITOR and NORMALIZE MODES. Press and hold both SELECT buttons for two seconds on the GEMINI 1200.

What are the TREND INDICATORS used for?

The up/down arrows give the pilot an indication of the most recent trend in each cylinder's EGT. Watch the trend arrows while leaning, or any time you want EGT trend information.

Why would I want to log temperature data?

Aviation training facilities find the GEM's advanced features valuable for educating pilots and mechanics in the complex science and art of engine management. A data-logging GEM can help you better understand your engine and keep it running efficiently and reliably. Researchers in engine and airframe development have used the GEM 602 and GEM 603 for over a decade. Now they are using the GEM 610 and GEMINI 1200 to data-log test-flights as part of the development and approval process.

Modern aircraft engines should run smoothly to TBO or beyond. When they don't, the operating history of the engine is often in question. The GEM's data-log can provide the type of information needed to resolve warranty disputes.

In the unfortunate event of a mishap, the GEM's datalog can serve the purpose of a "flight data recorder" for accident investigation.

Many pilots have found the GEM display indispensible for perfecting their engine management technique in flight. **Data-logging** allows the operator to review pilot technique on the ground post-flight. The permanent record of the engine's temperature performance can be analysed to identify inefficient or dangerous practices and adjust procedures to correct any problem areas.

The GEM's data-log is the perfect addition to a comprehensive maintenance program. While the GEM display gives the pilot the short-term trend information needed to monitor and manage the engine in real-time, the data-log contains the long-term trend data to track and predict failure modes.

A favorite issue of aircraft buyers and sellers is powerplant condition. A well maintained and properly run engine documented with a GEM data-log could only enhance resale value of an aircraft.

I don't have much computer experience. Will I need a Computer Science Degree to understand the GEM's data-log system?

Absolutely not! The GEM automatically records every flight and lets you transfer the data to your **HP palmtop** at your convenience. The data can be viewed immediately on the palmtop, or copied to your desktop personal computer, or just stored for future reference.

How much data can the GEM 610 or GEMINI 1200 store?

Hourly capacity of the GEM data-log varies depending on several factors including system configuration, condition of the aircrafts **ignition systems**, and pilot engine management technique. The data-log always contains the most recent flights. The GEM's data-compression system favors long flights with few power/mixture/altitude changes. GEM 610 users typically see 20 to 30 hours, GEMINI 1200 users see 10 to 20 hours.

How do I transfer data from the GEM to the palmtop computer?

Insight's software for interfacing with the GEM puts you in charge of the whole data retrieval process. Here is a quick run-through:

- Make sure the GEM is turned on.
- Run the GEMCOM program on your palmtop computer.
- Select DATA TRANSFER from the main menu.

Get a flight index from the GEM by selecting LIST ALL FLTS, then press ENTER and hold the palmtop up so the Infrared communication port is about six inches in front of the GEM. Hold it there long enough for the computer to get the flight index (fanfare indicates successful completion, buzz means that contact was lost).

Decide which files you would like to transfer and select a TRANSFER function (such as TRANSFER ALL). Hold the computer before the GEM and let the file transfer complete (fanfare on completion). The transfer should take no longer than four minutes even if the entire data-log is copied.

Are the data files removed from the GEM by the transfer operation?

The DATA TRANSFER function actually makes a copy of the GEM's data files and stores the new copy in the palmtop computer's file system. The original data files in the GEM's memory are retained until the GEM needs the storage space to record a new data file.

Why must the data-log files be EXPANDED to view the data?

The GEM 610 and GEMINI 1200 store data in a proprietary compressed-file format. FILE EXPANSION is Insight's terminology for converting the GEM's compressed IDF or ADF files into standard ASC (ASCII) format. The compressed files are extremely small in size for the amount of data they contain and therefore require little storage space in the GEM or on your computer. The small size also means they take little time to transfer.

The ASC files require much more storage space but are **ASCII** format (ASCII is the American Standard Code for Information Interchange) and are compatible with nearly every type of computer.

How can I look at the data once it's transferred to the palmtop?

The **palmtop computers** (**HP95**, **HP100**, and **HP200**) come with built-in applications that help you to manage and view your data in a variety of ways.

The FILER is a file management utility that lets you see what files are stored in the computer. It has the capability of copying and deleting files, and allows you to view the contents of a file. Use the FILER for a quick look at your GEM data files. Remember that data-log files with IDF or ADF filenames are compressed data format, files with ASC filenames can be viewed directly with the FILER.

The spreadsheet program (LOTUS 123) is designed to view and manipulate numerical data in a rows-and-columns format. Import data-log files with ASC filename into a spreadsheet (use the NUMBERS option) to take advantage of math functions and graphing capabilities.
Spend a few minutes reading the manual that came with your palmtop computer. Most operations require just a few button pushes.

How about copying the data from the palmtop to my desktop or laptop computer?

There are several different ways that data can be transferred from the HP palmtop computers; wired serial interface, wireless Infrared interface, and the PCMCIA card slot.

The wired serial interface is the most common method of transferring files, however Infrared communications and PCMCIA products are rapidly growing in popularity.

When is the best time to download my flights to my HP Palmtop?

The best time to download flights is after engine shutdown and avionics off. Power back up the GEM and then proceed with the flight download.

Note: Do not download flight data in flight.
Note: Starting in 1999 the infrared port on all GEM 610's and GEMINI 1200's models will be disabled during cruise flight.

To use the wired interface, a serial connection cable and data-communications software are required. Complete packages are available from several manufacturers. Consult your favorite supplier of computer products to determine the best method of interfacing the HP palmtop with your other computers.

Interface hardware and software options.

Hardware:

- Laptops - PCMCIA Slot
- External Flash Card Drive
- PCMCIA Floppy Storage Subsystem
- DOS-compatible Cable # HP F1015A

Software:

- HP Palmtop - 95, 100 and 200 - Data Comm
- Windows 3.1 - Terminal
- Windows 95 - 98 - Hyper Terminal or Winfile
- Mac. 7.5 - 8.5 Clairis Communications or ZTERM

Instructions, settings information and software can be found on our website: www.insightavionics.com

I want to graph and analyze my data-files on my desk-top PC. Are there any tools available for this?

The ASCII format data-files produced by Insight's GEM95 software are compatible with a wide variety of PC software. Spreadsheet programs are a standard application installed on most computers and lend themselves well to manipulating and viewing numerical data. Most spreadsheets now offer powerful graphing capabilities.

Suggested Reading

Books

Following are books of interest to owners and pilots of piston engine aircraft. If your local bookstore doesn't have these publications, the publisher can help you locate a copy.

The Major Overhaul

Kas Thomas, 1994
TBO Advisor Books
Post Office Box 625
Old Greenwich, CT 06870

Fly The Engine

Kas Thomas, 1993
TBO Advisor Books

Sky Ranch Engineering Manual

John Schwaner, 1991
Sacramento Sky Ranch Inc.
6622 Freeport Blvd.
Sacramento, CA. 95822
(916) 421-7672

EGT SYSTEMS

Kas Thomas and the Editors of
Light Plane Maintenance Magazine, 1989
Belvoir Publications Inc.
Greenwich, Connecticut 06836

Internal Combustion Engine Fundamentals

John B. Heywood, 1988
McGraw-Hill Book Company
1221 Avenue of the Americas
New York, New York 10020

Flying The Beech Bonanza

John C. Eckalbar, 1986
McCormick-Armstrong Co. Inc.
Publishing division
1501 east Douglas Ave.
Witchita, Kansas 67201

Aviation Safety's FLYING CIRCUS

David A. Shugarts and John M. Likakis, 1986
Belvoir Publications, Inc.
1111 East Putnam Avenue
Riverside, Connecticut 06878

Periodicals

These publications will keep you up to date on your aircraft and engine on a monthly basis.

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Temperature Probes

Insight designs and manufactures an extensive line of temperature probes. This section gives a brief description of our probes to help you identify the various types, and understand their application.

All of our engine probes utilize **thermocouple sensors,** the standard throughout the aerospace industry. Engine probes fall into three basic categories; CHT, EGT, and TIT.

Our OAT and IAT probes use a proprietary technology to give accurate, precise indications from the hottest day at sea level to sub-standard winter in the flight levels.

Cylinder Head Temperature (CHT) Probes

The Spring Probe is the standard **CHT probe**. It screws directly into the thermowell in **Lycoming** and **Continental** cylinder heads. All-stainless construction results in long, trouble-free life. The **J-Type thermocouple** has red and white color coded wires.

Figure 1. Spring CHT Probe P/N 2852

Gasket Temperature (CHT) Probes

Figure 2. Gasket CHT Probe P/N 2853

The **Gasket Probe** uses the same **J-Type thermocouple** as the Spring Probe. This probe replaces the gasket on 18mm spark plugs. The J-Type thermocouple has red and white color coded wires. Note that the spark plugs in some engines may run 50 to 100 Fahrenheit degrees hotter than the thermowell.

The gasket probe is recommended for use anytime the spring probe cannot be used. Aircraft fitted with thermowell TANIS preheaters should use the CHT Gasket probes.

Adapter Temperature (CHT) Probes

Figure 3. Adapter CHT Probes P/N 2855 and P/N 2856

Adapter probes are used in conjunction with original aircraft manufacture CHT probes. These probes are threaded to fit the cylinder head's thermowell.

The adapter probes are made in two styles, P/N 2856 is tapped to receive a threaded style OEM probe, and P/N 2855 for bayonet- mount OEM probes. Check your aircraft to see which type is appropriate.

Exhaust Gas Temperature (EGT) and Turbine Inlet Temperature (TIT) Probes

Figure 4. TIT Probe P/N 2871, EGT Probe P/N 2870

Our standard **EGT** and clamp **TIT probes** are similar in construction. EGT P/N 2870 uses a 21/4" stainless steel hose clamp, TIT probe P/N 2871 uses a 31/4" clamp. Both employ a **K-type thermocouple** with red and yellow color coded wires.

The 4871 Dual TIT probe(not shown, yet similar in construction to P/N 2871) contains two separate thermocouples for both GEM and OEM TIT gauges.

Turbine Inlet Temperature (TIT) Probes

Figure 5. TIT Probe P/N 2872 Threaded with boss,
TIT Probe 1/4 NPT P/N 2873

P/N 2872 comes complete with 1/2" boss to be welded into the turbo inlet. P/N 2873 utilizes 1/4 NPT compatible with many PIPER turbo installations.

P/N 4872 Dual TIT probe and P/N 4873 Dual TIT probe,(not shown above) each contain two separate thermocouples for both the GEM and OEM TIT gauges.

Outside Air Temperature (OAT) and Inside Air Temperature (IAT) Probe

Figure 6. OAT/IAT probe P/N 1200-021

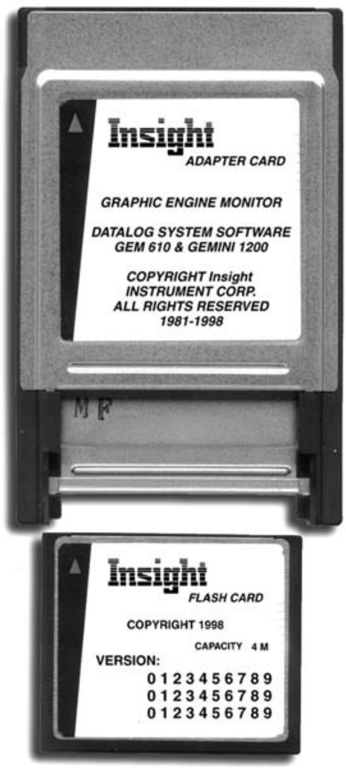
The Insight **OAT/IAT probe** give accurate and precise measurements of the air temperature inside and outside the cabin. Locating the IAT probe in the rear of the cabin allows the pilot to monitor the comfort level in the last row of seats.

Computer Accessories

Computer Memory (RAM or FLASH) Cards

Figure 7. 1M RAMcard

or



4M Flash Card

The **RAMcard** provides easy memory expansion and datafile storage for the HP computer. The lithium back-up battery should be replaced annually to prevent loss of data or programs.

The **4M Flash Card** has no battery back-up and also provides easy memory expansion and datafile storage for the HP computer.

Warranty and Service

Warranty

The **Insight Instrument Corporation Graphic Engine Monitor** temperature display instrument 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.

GEM Technical Support

If you have difficulty installing or using a GEM system, please read the GEM's documentation. Every GEM system is shipped with complete instructions for installation and use. The answers to many technical questions can be found in this booklet, or the GEM Installation Manual. Insight provides customer support free of charge for as long as you own the instrument. If you have any questions concerning GEM 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.

GEM Model No. ______________________________

GEM Serial No. ______________________________

Aircraft Type: ______________________________

HPLX Technical Support

Answers to questions about the use of the HPLX's built-in applications (FILER, 123 Spreadsheet, etc.) are found in the HPLX User's Guide and HPLX Quick Start Guide. Telephone numbers for Hewlett-Packard are in the HPLX's manuals.

Educational Video

To assist our customers in installing and using GEMs, Insight has produced an educational video tape entitled ***Modern Engine Management***. Our video is available free of charge. Call or write to obtain your personal copy of this classic production.

Service Procedures

Like many modern electronic devices, the GEM is extremely reliable. Other than configuration during installation, the GEM requires no adjustment or routine maintenance. Should you suspect a malfunction, perform the self-test described under **Test Mode**. If the GEM fails this test, it must be returned to the factory for service. If the instrument performs the self-test successfully, discuss the problem with your dealer, or consult the troubleshooting section of the *GEM Installation Instructions*. Keep in mind that in the vast majority of cases, erratic or unusual GEM operation can be traced to an installation problem, a problem with probes, wiring harness or the aircraft's electrical system. The instrument itself is the least likely source of trouble. For this reason we encourage you to contact Insight Customer Service at one of the numbers listed below before returning an instrument to the factory, or any time you have any questions concerning the operation of the GEM.

Contact Phone numbers:

(905) 871-0733

Disclaimer

In the event that an instrument must be returned for service, call Insight before shipping. Be sure that you or your dealer include an accurate description of the problems you are experiencing. A business card or note with a contact name and phone number taped directly to your GEM will greatly assist our technicians in servicing your instrument. Your repaired instrument will be returned to you or your dealer shipping prepaid.

Like all instrumentation, the GEM requires careful and knowledgeable interpretation by the pilot. Any recommendations and operating procedures contained in this manual shall not supersede aircraft or engine manufacturer's recommendations, operating procedures or limits. The GEM should not be used to exceed the aircraft and engine manufacturer's operational limits and recommendations. **Insight Instrument Corporation** is not liable for any damages resulting from the use of this product.

Glossary

ASCII American Standard Code for Information Interchange.

Best economy mixture
The mixture or fuel/air ratio producing the optimum ratio of horsepower to fuel consumption. This mixture is generally found at an EGT around 50°F on the lean side of peak.

Best power mixture
The mixture or fuel/air ratio producing the most power from a given amount of fuel. This mixture is generally found at an EGT around 125°F on the rich side of peak EGT.

Booststrapping
A condition which can occur in turbocharged aircraft in high altitude cruise (with the wastegate closed; *See Wastegate below*), in which large, unexpected manifold pressure excursions take place spontaneously. The manifold pressure instability is due to feedback loop effects in the turbo system. The usual "cures" are to increase engine rpm and/or open the wastegate.

Camshaft
A shaft that runs at half of normal engine (crankshaft) speed, with metal lobes on it to trip open the engine's intake and exhaust valves at the right time and in the right order. Camshaft action determines valve action.

Charge
Fuel-air charge; the incoming of fuel and air as it arrived at the combustion chamber.

CNC
Computer Numerical Control

Critical altitude
In a turbocharged aircraft, the altitude above which sea level rated manifold pressure can no longer be maintained; or the altitude above which the *wastegate* is closed all the way, all the time.

Cylinder Head Temperature (CHT)

The temperature of the head portion of the cylinder, as measured by a thermocouple placed either in the spark plug area or a threaded boss in the head. The head portion of the cylinder contains the combustion chamber dome, the valves, valve springs, rockers, intake port, and exhaust port. Overheating of the head can occur easily in an air cooled engine, hence the need for CHT instrumentation.

Detonation

Combustion knock; the premature, spontaneous auto-ignition of the unburned fuel/air charge ahead of the flame front, in a combustion chamber in which discharge of the spark plug(s) has already occurred. In other words, the a spark event has taken place at its time, fuel and air are present, and a portion of the fuel and air mixture has begun burning. However, the unburned portion (compressed by the expansion of the burning charge) reaches a pressure and temperature sufficient to cause a sudden explosion of the entire charge. This produces the familiar knocking sound in an automobile engine. It also produces mechanical stresses which can eventually fail rings, pistons, connecting rods, or cylinder heads or valves. In an airplane engine, the *ping* or *knock* sound cannot usually be heard from the cockpit. Hence it is especially important for a pilot to avoid letting an engine detonate in the first place. Detonation can be caused by fuel of insufficient octane rating, or (with proper octane fuel) operation of a very high power output with a very lean mixture. Improperly advanced magneto timing will also hasten the onset of detonation, as will heating of the incoming fuel-air charge (by carburetor heat or by compression via turbocharger).

DSP

Digital Signal Processing

IFR

Instrument Flight Rules

Induction system

Generally, the entire air intake system of the engine, from the air filter (or airscoop) to the intake ports.

Leanest cylinder

The cylinder that operated at the lowest over all fuel/air ratio compared to the other cylinders in the engine. By the EGT method, leanest cylinder is defined as the cylinder that reaches peak EGT first during progressive leanout.

LSI

Large Scale Integration.

Manifold pressure

The pressure, in inches of mercury, of air within the engine induction system downstream of the throttle butterfly. This pressure is directly related to air flow and hence (under most circumstances) engine power output.

NPT

National Pipe Thread.

OEM

Original Equipment Manufacturer.

Preignition

Ignition of the fuel-air charge in a cylinder before normal discharge of the spark plug. In a broad sense, anything that causes combustion to occur before the specified ignition timing (as set forth on the engine data plate) could be said to be causing preignition. Thus, even the aircraft ignition system -if maladjusted- could cause preignition to occur. Because, of the abnormal stresses induced, preignition can be extremely damaging to an engine, and at high power settings the damage can occur very quickly (often in less than 30 seconds). Operation with detergent-type automotive oils can cause preignition due to ash deposits (from the Barium and Calcium containing detergents) which leaves hot spots in the combustion chamber. Hence, the use of "ashless dispersant" oils in aviation. If piston or rod failure does not occur first, preignition will make itself evident by a very high CHT indications.

Pressure ratio

In turbocharging, the ratio of outlet to inlet pressure at the turbo compressor.

Supercharger

Generally, any device that forcibly increases the amount of air flow by an engine's induction system. Although technically speaking a turbocharger is a type of supercharger. Today the word is usually used to connote a mechanical supercharger (that is a fan or pump driven mechanically off an engine's crankshaft.) Mechanical superchargers can be found on many radial engines, and on certain 480 and 540 cubic inch Lycoming engines.

TCA

Terminal Control Area (Class B Airspace).

Thermocouple

A junction between two dissimilar metal alloys in which a small voltage is produced which varies with temperature. The voltage is produced because different metals have different tendencies to "donate" their electrons. Different alloys are used in thermocouples for different heat range applications.

TBO

Time Between Overhaul.

Turbocharger

Also sometimes called a "turbosupercharger." A turbocharger is an exhaust driven supercharger, used for increasing the manifold pressure, and therefore the total power output of an engine.

Wastegate

A control valve (which may be of either the butterfly or poppet type) in the exhaust system which governs the flow of exhaust to a turbocharger turbine. Usually there is a 'Y' in the exhaust system, with the wastegate on the one arm of the 'Y' and the turbocharger itself on the other arm. Since the exhaust must pass through one of the arms before leaving the engine, closing the wastegate increases the flow through the turbocharger/wastegates may be manually controlled or automatically actuated via a bellows-type aneroid controller, depending on the installation.

Cover Story

Case History

This case history is presented in the interests of economy and safety of flight. Analysis of the GEM datalog provides an excellent educational tool for understanding the complex relationships of engine management.
With the Advanced Graphic Engine Monitoring with Data Logging provided by Insight's GEMINI, Daniel Knopper, an Aerostar Owner, was able to download critical in-flight engine behavior, as described and shown in this 3D graph, when his Aerostar Lycoming Engine failed due to detonation.

Daniel Knopper in his own words says;

"After landing safely, the stored data of Insight's Graphic Engine Monitor provided indisputable proof of proper operation to the overhaul facility for full warranty. Besides the unit showing the detonation of the failed cylinder, it revealed two additional cylinders encountering detonation range temperatures that normally would have gone undetected. Physical evidence was present on inspection of these cylinders and they were replaced by the rebuilder without any question.
Self diagnosis, trend monitoring and cost benefits don't compare to the restored peace of mind I have flying my Aerostar."

Discussion of Factors

Aircraft:	Piper Aerostar 602P (Twin engine turbocharged pressurized high-performance six passenger)
Engine:	Lycoming TIO-540-AA1A5 290 HP
Background:	Maintenance Intensive aircraft. A history of engine failures and in-flight engine shut-downs preceded installation of two new Engines and a GEMINI 1200 Graphic Engine Monitor.

Abnormal combustion process:

Detonation and Pre-ignition are used to describe the same conditions within an engine. When diagnosing an engine failure, it is vital to know whether detonation or pre-ignition caused the engine failure.

Detonation and pre-ignition are totally separate conditions in terms of what they are and what damage they do. Detonation is caused by the spontaneous combustion of fuel in the combustion chamber verses a normal even desired burn. Detonation causes high cylinder head temperatures and low exhaust gas temperatures creating a pinging noise, that in aircraft engines you cannot hear.

Pre-ignition is premature ignition of the fuel/air mixture before the spark while the compression stroke is occurring, but earlier than desired. Pre-ignition can cause extremely high temperatures in a short time.

Causes of Abnormal combustion process:

Detonation can lead to pre-ignition if hot spots develop in the combustion chamber. Pre-ignition leads to detonation if combustion chamber temperatures raise the gas/air mixture to a high enough temperature to ignite spontaneously.

Detonation is caused by:

- Too high a compression ratio for the octane of fuel used.
- Too lean a fuel mixture, which slows the fuel burn and appears as an advance in timing.
- Hot spots in the combustion chamber.
- High power settings.
- Pre-ignition

Pre-ignition is caused by:

- Using an incorrect spark plug.
- Hot spots in the combustion chamber.

Symptoms of Detonation/Pre-ignition:

CHT is usually increased, EGT may be decreased. Due to the wide variety of factors affecting CHT and EGT there is no simple or obvious way to detect abnormal combustion process!

Fuel Quality:

A fuels octane rating describes it's ability to resist detonation. Turbocharged engines require high octane fuel to offset the detonation inducing affects of high cylinder pressures and temperatures. Contamination of fuel by alcohol, jet-fuel or a lower grade of gasoline reduces it's octane-rating.

Injector Nozzles:

Restriction of fuel-flow by nozzle clogging increases back-pressure on the fuel system. This causes an increase in indicated fuel-pressure while fuel-flow is actually decreasing!

Pilot Technique:

Normal Aerostar Pilots Operating Handbook (P.O.H) recommended procedures were employed by the flight crew. Crew consisted of pilot/ owner and maintenance chief. Both highly experienced on aircraft type.

Aircraft Status:

Fresh premium-rebuilt right engine. Low-time premium-rebuilt left engine. Newly-installed GEMINI 1200 system.

Prelude to Engine Failure

The aircraft departed a sea-level airport and performed a P.O.H. normal climb to 19,000 ft. Both engines appeared to operate normally in the climb. Level cruise flight was established at flight time 0.40. Cruise power was set and the right engine was leaned to P.O.H. recommended fuel-flow. All engine temperatures and pressures indicated well within normal operating ranges.

Post Flight Investigation

After the incident, the customer contacted Insight for help. Based on Insight's analysis of the data log file, the hidden damage to cylinder 3 was revealed. The abnormal CHT's recorded in cylinder 3 and 5 forewarned of the detonation damage found in cylinder 3 and the failure of cylinder 5. These findings compared exactly to the easy to read picture the GEM displayed for it's owner.

Left engine cylinder head 5 had separated from the cylinder barrel. Cylinder head 3 was found to be cracked. Had the pilot not shut down when he did, this cylinder would have failed too.

The GEM's datalog analysis allowed the engine's real problem to be traced to its root cause. The fuel injection system was contaminated. The analysis also revealed hidden damage to cylinder 3. This cylinder would have certainly failed on a subsequent flight. Following these repairs the engine has been trouble free.

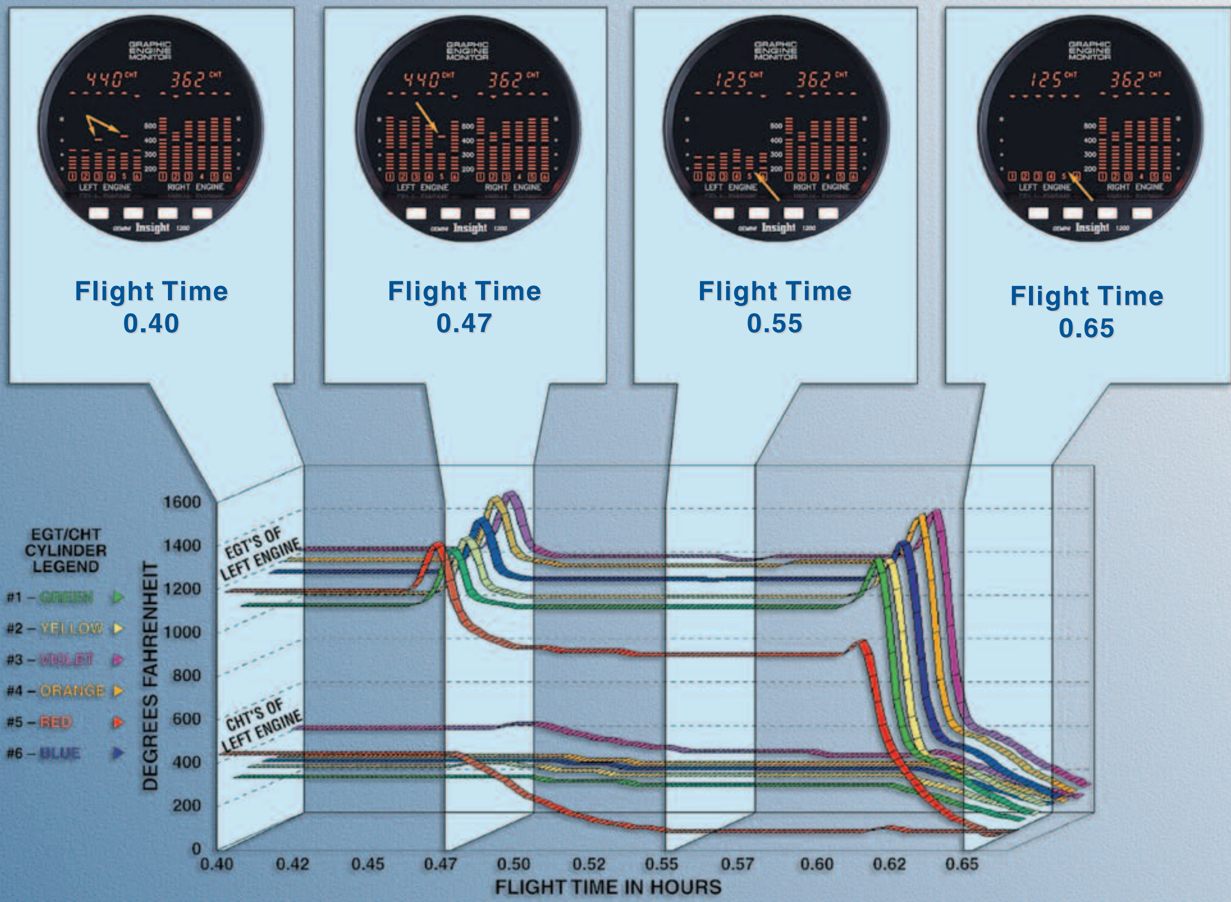
Recommendations

1) Regular frequent cleaning of fuel injector nozzles is highly recommended to reduce the likely-hood of injector clogging.

2) Always supervise fueling of the aircraft. Check fuel for correct octane rating and evidence of contamination.

3) When detonation is suspected in-flight, take these steps:
   a) Enrich the mixture.
   b) Reduce the throttle setting.
   c) Investigate the possible causes: clogged injector nozzle, contaminated fuel, overboost?

4) Know your engine. Each engine has a unique pattern of EGT and CHT for each combination of power and mixture settings. Regularly download datalog and compare with engine's historical performance to detect intermittent and subtle changes in temperature patterns.



Flight Time 0.40

Cylinders 3 and 5 are running higher than other cylinders as shown in the above display. The increased CHT's were within normal operating range. The **GEM's** data logging of engine performance clearly shows the CHT's normal pattern of operation.

Flight Time 0.47

The only symptoms are a slight drop in manifold pressure and a slight airframe vibration, that could easily go undetected. Only the **GEM,** clearly shows a sudden drop in cylinder 5 EGT, indicating possible cylinder failure.

Flight Time 0.55

The gradual loss of CHT in cylinder 5 as shown here by the **GEM**, verifies failure of that cylinder. All other cylinders continue to operate normally. Failure of cylinder 5 as clearly shown by the **GEM,** prompted the pilot to immediately shutdown the left engine.

Flight Time 0.65

The **GEM** display clearly shows that immediate shut-down secured the left engine to prevent further damage. Right engine continues to operate normally.