Getting The Most Out Of Your EGT

Exhaust gas temperature (EGT) systems are now common, but few know how to get optimum benefits from such systems, says author. Recommendations proposed for engine manufacturers, as well as users

by AL HUNDERE / AOPA 42710

■■ The simplification and optimization of EGT for mixture control is greatly dependent on the issuance of the proper specifications and instructions from the engine manufacturers. At present, too much is left up to the judgment of the airframe manufacturers and the pilots.

One of the most important steps that could be taken in this area would be to standardize the dial presentations on EGTs, so they would be more descriptive and easier to understand. A recommended dial presentation is shown in Figure 1. Using this type of presentation, all the pilot would really have to remember is *keep the EGT in the green* [solid color] *at all times*—takeoff, climb, cruise, and descent.

The "G" marked on the dial in Figure 1 is to indicate the normal EGT during ground runup, say 1,700 rpm. The reference mark (*) is peak EGT at fixed cruise condition, such as 75% power, 2,300 rpm, and 7,500 feet for the Phantom IO-567 engine. The engine manufacturer should also give actual temperature values with limits for the reference mark, such as 1,525 ± 25°F for the IO-567 engine.

EDITOR'S NOTE: *It has been nearly 10 years since the EGT (exhaust gas temperature) method of mixture control was introduced. EGT installations reportedly now total over 50,000. The EGT indicator has become standard equipment on many aircraft, latest being the new Piper Seneca [Jan.* PILOT, *page 36]. There is still some apparent confusion and misunderstanding as to how to obtain optimum use of this instrument, and the editors asked Al Hundere (AOPA 42710), president, Alcor Aviation, Inc., San Antonio, Tex., to see if he could help in this respect. This article is the result of that plea. Hundere, whose company manufactures EGTs, is a recognized aviation fuels expert and he has occasionally been asked in the past to author articles for* The PILOT *in his field of expertise. He earlier wrote an EGT article, called "Analyzing Your Engine's Health," which was published in the Aug. 1966* PILOT.

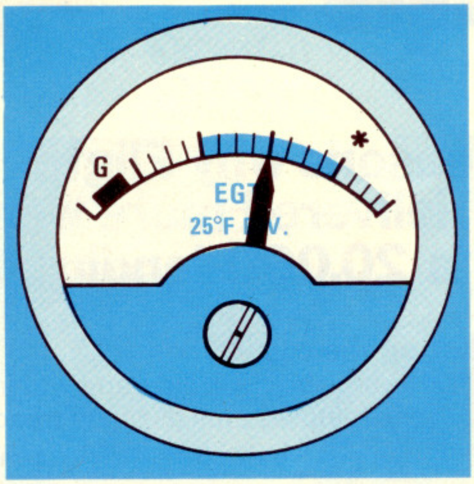


Figure 1—Author's proposed dial and range markings for EGT systems. Solid color area would be green; lighter area, yellow.

As a result of not specifying a normal EGT value for the reference mark, abnormal EGT readings are all too often blamed on the EGT system. Then, when an engine failure occurs, it is often realized too late that the EGT indicator was truly giving a warning of impending engine trouble.

If you like the Figure 1 dial presentation, then the primary question probably is "Fine, but how does one utilize the above information for a Continental IO-470 engine, a Lycoming O-360, or some other engine with the existing EGT dial?" The following is proposed:

1. Keep a mental picture of the green arc [solid color] and yellow arc [lighter color] of Figure 1, i.e., green arc extends 200°F below the reference point and the yellow arc above.

2. Select conditions for the reference point, such as peak EGT at 65% power at that altitude where full-throttle is reached for 65% power.

3. Establish where Point "G" is on the dial (important for operating from high altitude airports with engines having uncompensated fuel metering systems). Establishing Point G can be done by observing the EGT at full-rich during ground runup when at sea level or near sea level, assuming, of course, that the fuel flow at full-rich at sea level is correct. Also "G" can be established by: (1) setting off full-power in flight at minimum altitude; (2) leaning the mixture so the EGT is at the center of the green arc; then, (3) after landing and before moving the mixture control, go to ground runup conditions; and (4) observe the EGT reading and use this "G" value. Based on my flying experience, "G" for the Continental fuel-injection engines is as shown in Figure 1.

4. It is also recommended that a record be kept in the engine logbook of the EGT value at the reference point, such as 1,525°F or whatever it may be. After initial installation, this can be determined by the deviation from the factory calibration stamped on the meter; this, however, is not the most accurate. The most accurate method is to apply heat to the probe to determine the true temperature required for an EGT reading at the reference. Any time an abnormal EGT reading is observed, the calibration of the system should be checked to determine whether the EGT system went off calibration, or whether engine trouble exists. There have been many cases where abnormal EGT readings have been ignored and an engine failure, or a shorter than expected time between overhaul (TBO), resulted therefrom.

The preceding should not be interpreted as recommending deviation from the engine manufacturer's leaning instructions. What *is* recommended is that this information be utilized to obtain optimum performance within the limitations set by the manufacturer, and to detect abnormal mixtures that are harmful, as well as detecting EGTs that warn of engine trouble.

For example, take the case where, at full-rich takeoff power, the EGT is well up in the yellow arc. If this is not corrected, a short TBO or even engine failure can be anticipated. Many such cases have been reported and when the necessary engine adjustment or modification is made, such as changing to bigger fuel nozzles, the TBO returns to normal.

In addition to standardizing on a dial presentation, engine manufacturers should also issue specific instructions on the location of the exhaust probe, so as to give a consistent fuel flow for a given EGT setting. The option now permitted in the location of the exhaust probe can readily result in a 10% difference in fuel flow from installation to installation (this is for an EGT spread of 150°F between the richest and leanest cylinders, which is not uncommon). Lycoming states, "The exhaust temperature probe *should* be located in the exhaust of the leanest cylinder." For fuel-injection engines, Continental says "the exhaust temperature probe may be located in either an exhaust stack or the exhaust manifold of several cylinders. However, the exhaust stack of cylinder No. 1 or No. 2 is preferred." Some airframe manufacturers like to locate the exhaust probe at the cluster, so as to show greater range, but this can result in the leanest cylinder operating on the lean side of peak when the EGT is set as specified. The engine manufacturers should give specific instructions on the location of the exhaust probe such as, "The exhaust probe *must* be located ————————."

The answer to "How lean is too lean?" is often misunderstood. The opinion that excess fuel will increase engine life is as erroneous as taking two pills when the doctor prescribes one. There is ample evidence that too much fuel can do as much harm as too little fuel. Too much fuel contributes to increased spark plug fouling and increased combustion chamber deposits. The latter can cause momentary preignition that can result in engine failure.

For example, a twin-engine aircraft owner was operating 50 degrees on the rich side of peak EGT during cruise and was experiencing a cylinder failure every 600 hours but when he went to a richer mixture setting, 100°F off peak, the time to cylinder failure was decreased, not increased, as he had anticipated. What he didn't know was that it was his richest cylinders failing and he simply aggravated the problem by going richer. What happened could have been avoided if he had had the information that an EGT engine analyzer provides.

Current state of the art on the question "How lean is too lean?" can be summed up as follows:

1. By far the major problem resulting from being too lean is at power settings used for takeoff and climb, rather than cruise. Keeping the EGT in the green arc as required to control cylinder head temperature will assure proper mixture for all full-power operation, providing the EGT being read is that of the leanest cylinder, or providing there is only a small difference between the leanest cylinder and the cylinder, or cylinders, at which the exhaust probe is located. All too often, a cylinder not sensed by the EGT indicator becomes significantly leaner through some malfunction, such as a restriction in a fuel nozzle, a leaky intake pipe, or what have you. The result is usually cylinder failure from excessively lean mixture during full-power operation. The only way to prevent such failures is by having the information that can be provided by an "EGT Engine Analyzer" that monitors the EGT from all cylinders so that corrective action can be taken in time.

2. For cruise, it has been well proven that up to 65% power, peak EGT is not too lean and is the best mixture setting for maximum range. Going leaner than peak EGT increases range, primarily through reduction in power, i.e., the increase in range obtained by operating at 50°F off peak on the lean side can also be obtained by staying at peak EGT and reducing the airspeed to the same value through power reduction. If the fuel-air distribution between cylinders is poor, however, then going on the lean side of peak EGT for the leanest cylinder will result in some improvement in fuel economy. Lycoming's Service Instruction 1094C, dated Jan. 31, 1969, encourages operation at peak EGT to obtain fuel economy by stating, "Lean to peak EGT whenever best economy operation is permitted by the airplane owner's handbook or the engine operation manual."

3. There have, however, been cases called to my attention where cylinder failure, or short TBO, has resulted when operating at peak EGT at 65% power for cruise. These cases though, resulted from a combination of two conditions. First, the cylinder or cylinders that failed were operating not at peak EGT but on the lean side of peak, either due to having the exhaust probe on other than the leanest cylinder or having the probe located at the cluster of cylinders where there was appreciable difference between the richest and leanest cylinders of the cluster. The second factor involves having an exhaust valve material that cannot withstand an oxidizing atmosphere at the exhaust temperature involved. The engine manufacturers report they are currently using exhaust valve materials that will withstand these conditions. Even if the exhaust valve material is such that it will normally withstand the environment resulting from being on the lean side of peak EGT at cruise power, a critical oxidizing temperature can result if the valve doesn't have the proper alignment and seat contact area. There have been cases where the products of oxidation have supported preignition and sudden engine failure.

One should avoid operating any cylinder on the lean side of peak EGT. One approach is to use excess fuel for cruise, but then the pilot runs the risk of getting into trouble with the richest running cylinder. The optimum solution, of course, is to utilize an EGT engine analyzer, so that the leanest cylinder can be monitored at all times, no matter how it might change locations. It is common with carburetor engines for the leanest cylinder to change location with throttle position. In fact, the change is sometimes so great that the leanest cylinder at full-throttle is the richest cylinder at some part-throttle. Keep in mind that each cylinder is, in itself, a separate engine, but the failure of any one results in the failure of the entire engine. To depend on the EGT reading from a single cylinder for indicating the health of the entire engine is comparable to flying a twin-engine airplane with engine instrumentation on only one engine, then assuming the other engine will have the same readings if the controls for both engines are set the same. Ask a pilot who has used an engine analyzer over a significant time period. Like the S-Bonanza owner who said, "Yes, with my EGT engine analyzer I believe that I so closely approach twin-engine reliability that I have canceled my plan to move up to a twin at this time."

A major problem in utilizing an EGT engine analyzer is that of understanding the variation in peak EGT from cylinder to cylinder. If an engine has the same airflow to each cylinder, good ignition and all cylinders in good condition, then all cylinders will peak at the same airflow to each cylinder, good In this case, when richer than peak, the cylinder with highest EGT is leanest, and although this is the normal situation, it is not always the case, as shown in 2b.

In this latter case, all cylinders peak at the same fuel flow as shown in Figure 2a but the leanest cylinder, No. 1, no longer has the highest EGT. In such a case, don't make the common mistake of concluding that the exhaust probe is faulty, because it could be a serious engine problem, such as an intake valve with low opening possibly caused by faulty valve lifter.

When a low peak EGT reading is observed for any cylinder, the pilot or mechanic should first determine if the problem is with the exhaust probe. This can be best accomplished with an AlCal EGT System Tester (to be described later), or by switching probes with one

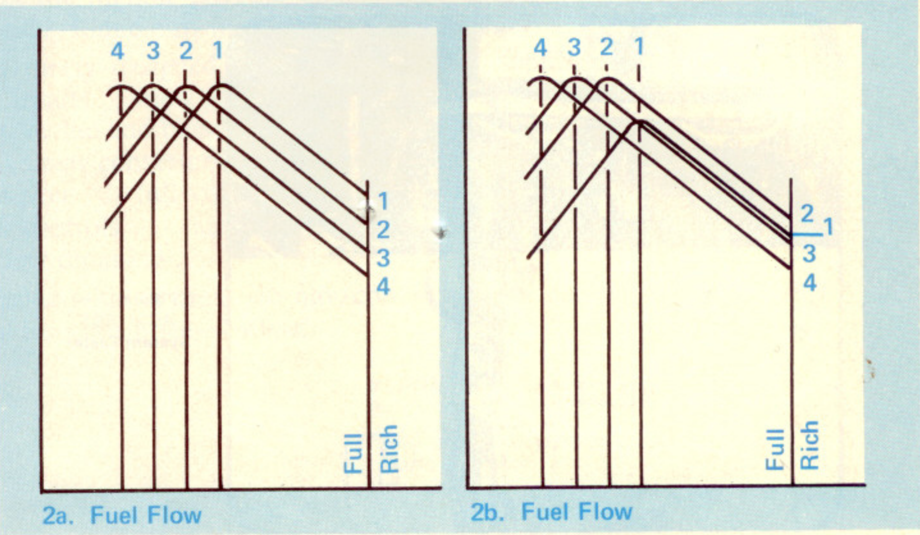


Figure 2—Mixture distribution, four-cylinder engine.

of the adjoining cylinders to see if the low reading stays with the probe or the cylinder. (It is an entirely different situation when an abnormally high EGT reading is observed, because the cause then is definitely the engine.) A high EGT reading cannot be blamed on the exhaust probe, because everything possible that can go wrong with an exhaust probe will cause a *decrease* in EGT reading, *not an increase*. Keep in mind the primary purpose of an EGT engine analyzer is to protect all cylinders against excessively high EGTs.

After considering the preceding pertaining to Figure 2, you may be wondering whether it is necessary to plot such curves in order to determine whether the cylinder with the highest EGT is truly the leanest. The answer is definitely "No." When an EGT engine analyzer is first installed, it is advisable to get acquainted with the mixture distribution pattern, including determination of the peak EGT reading for as many cylinders as possible before getting to lean misfire. Thereafter, any time it is suspected that another cylinder other than the one with the highest EGT is the leanest, then the simplest procedure is to lean the cylinder with the highest EGT to peak, select the other cylinder in question, and enrich the mixture just enough to see some pointer travel. If the EGT decreases, the cylinder is not leaner. If it increases, it definitely is leaner. This same procedure can then be followed for any other cylinder.

Another misunderstood aspect of EGT systems is that of accuracy and reliability. In the battle to give maximum value at the lowest possible cost, embarrassing malfunctions in the early period of EGT systems resulted. However, the reliability battle has been won through design changes.

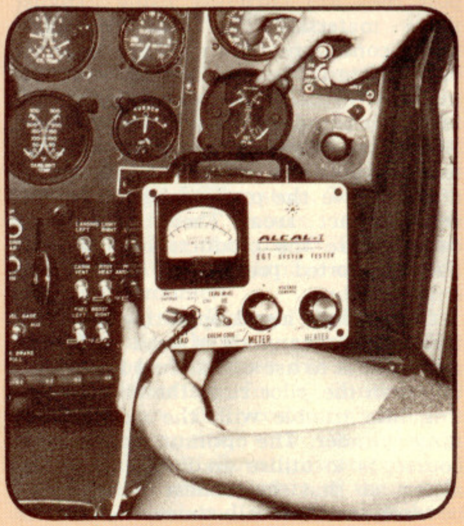
Exhaust probe life normally exceeds 1,000 hours and sometimes exceeds 3,000 hours. Recently, the exhaust probes from an engine-analyzer-equipped Twin Comanche were tested after 1,417 hours. One probe had failed, but the others were all within 25 degrees of each other when calibrated at 1,600°F.

What more can be done to obtain greater accuracy and reliability? Zero defects in design and manufacture is only a part of the answer. The major problem is that the vast majority of aircraft maintenance shops are not equipped to check out and troubleshoot such instrumentation. Proof of this is the fact that about 75% of the exhaust probes and meters returned for repair or warranty replacement have absolutely nothing wrong. For example, one shop—after replacing the probe three times and the meter an equal number of times—returned, in disgust, the entire indicator kit for refund. The problem was that the lead wire was damaged when it was put through the firewall, causing an intermittent short.

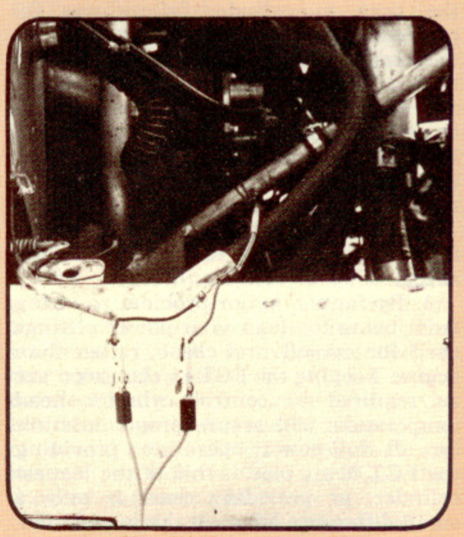
The solution, of course, is to have all shops installing and maintaining EGT systems equipped with the proper test equipment. A radio shop would play havoc in trying to maintain your radios without the proper equipment for troubleshooting. The same goes for the EGT systems. The reason proper test equipment has not been made available to date has not been the lack of effort but, simply, the money barrier involved. The JetCal Tester used for EGT systems on turbine engines costs about $3,000, and something for a tenth of this amount is needed for piston engines in order to get it into all the shops that should be so equipped. The AlCal EGT System Tester is such an instrument and it is shown in use in Figure 3. A reference EGT indicator is located in the cabin, as shown in Figure 3a, for comparison with the aircraft-installed EGT indicator. In troubleshooting, the red lead at the exhaust probe is disconnected and alligator clamps are connected as shown in Figure 3b. The mechanic in the cabin in Figure 3a can then adjust a knob on the tester to apply a signal equal to the desired temperature.

By using such a test unit, the aircraft indicator also can be checked for friction in the meter movement, poor connections, shorts, etc. To make a true calibration, the exhaust probe is heated electrically, as shown in Figure 3c. At full voltage, a temperature of 1,650°F can be obtained in about three minutes. The temperature of the probe furnace is controlled from the test box as shown in Figure 3a and the true temperature is read on the reference meter which, in turn, can be precisely checked against a standard at any time the mechanic might question the reading. This all might seem complicated but it is really quite simple and with a price tag of only $299 for the AlCal EGT System Tester, any shop can readily afford one.

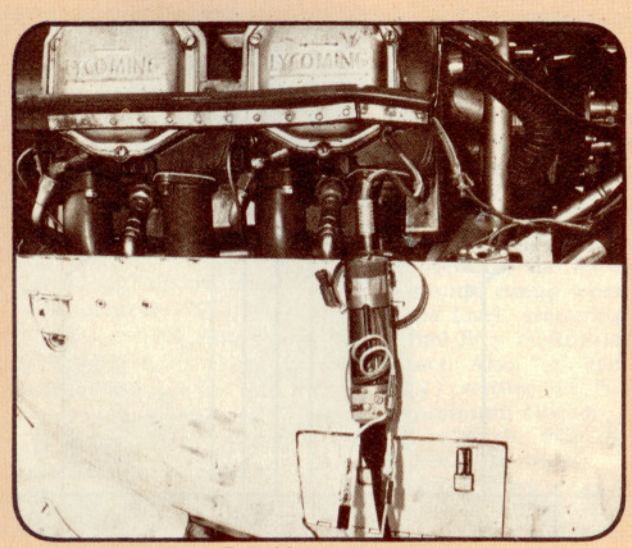
In summary, optimum utilization of EGT can contribute much to making flying safer and better—may your flying be such. □



3a. Test box in cockpit.



3b. Voltage test.



3c. Heat test.

Figure 3—AlCal EGT System Tester