EGT Myths Debunked

derstanding exhaust gas temperatures

IKE BUSCH

TS STILL SEEM TO have a lot of misconceptions about exhaust gas perature (EGT). Let's see if we can clear some of them up.

These days, pilots of piston-powered aircraft seem to be fixated n EGT. Scarcely a day goes by that I don't receive a phone call, ail, or support ticket asking some EGT-related question. Pilots will send me a list of EGT readings for each of their cylin- s and ask me if I think they look okay, whether I think their EGTs too high, what maximum EGT limit I recommend, why their Ts seem to be higher in the winter than in the summer, or why EGTs on their 1972 Cessna 182 are so much higher than the ones heir friend's 1977 model. They'll voice concern that the individ- cylinders on their engine have such diverse EGT readings, worry t the spread between the highest and lowest EGT is excessive, l ask for advice on how to bring them closer together. They'll plain that they are unable to transition from rich-of-peak (ROP) ean-of-peak (LOP) operation without producing EGTs that are acceptably high.

Each of these questions reveals a fundamental misunderstanding what EGT measures, what it means, and how it is interpreted. me attempt to clear up some of this confusion by asking you to get everything you thought you knew about EGT and start at beginning.

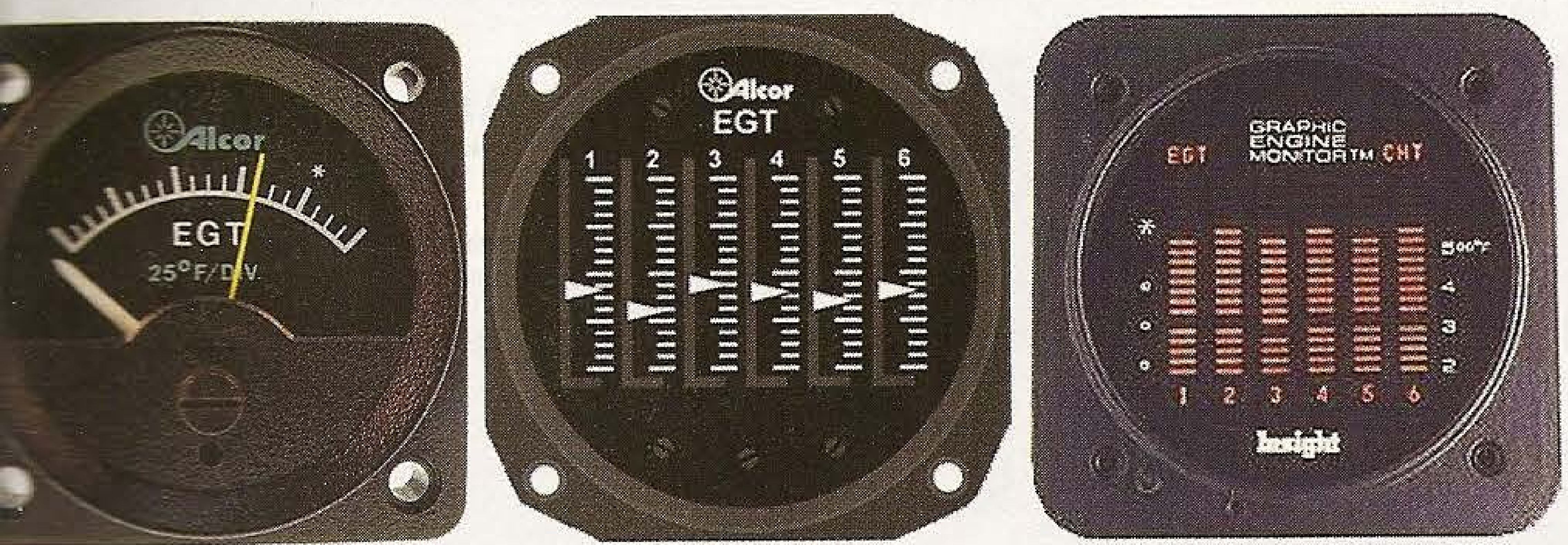
TTLE HISTORY

en petroleum engineer Al Hundere introduced the first EGT trumentation for piston-aircraft engines in the 1960s, he did ething quite clever. The analog EGT gauges manufactured by his mpany Alcor (and widely installed by Beech, Cessna, Mooney, er, and other aircraft manufacturers) had no absolute tempera- e markings, only a series of unlabeled tick marks spaced 25 grees Fahrenheit apart, with an asterisk at 80 percent of full-scale (See Figure 1). As the pilot leaned the engine, the EGT needle rose to a peak value on the meter, then started to fall off. The pilot would note where the needle peaked, then would richen until the needle dropped by the desired number of tick marks (e.g., three for 75 degrees Fahrenheit). The gauge provided the pilot no way to determine the *absolute* value of EGT (e.g., 1,475 degrees), but only its relative value (e.g., 75 degrees rich of peak).

Hundere understood that the absolute value of EGT is not particularly meaningful (we'll see why shortly), and that presenting this information to the pilot would simply be a distraction. Since the Alcor EGT gauges provided no absolute temperature information, pilots never worried about whether their EGTs were too high or what the maximum EGT limit should be—and that was a good thing.

The first probe-per-cylinder engine analyzers introduced by Alcor and Bill Simkinson's KS Avionics were arrays of vertical analog meter movements, and they also provided only relative EGT information to the pilot. When John Youngquist introduced the original Insight graphic engine monitor (GEM), its novel LED bar-graph display also provided only relative EGT.

GURE 1



The original Alcor EGT gauge provided no absolute temperature information; the same was true of early engine analyzers and even the original Insight GEM 601/602.

Things started getting confusing when Electronics Interna (EI) introduced its Ultimate Scanner that provided digital (rat than graphical) readouts of EGT, and touted its 1-degree Fahre accuracy as being far superior to the 25-degree granularity of t GEM's bar graph. (Never mind that the absolute EGT values it reporting so accurately were essentially meaningless.) Not to b outdone, J.P. Instruments (JPI) introduced its EDM-700 that f tured both a GEM-like bar graph and an Ultimate Scanner-like digital readout on the same instrument (See Figure 2). The ED 700 was a smashing market success and forced both EI and Insight to respond with similar products (the UBG-16 and GE 610, respectively).

Now pilots were being presented with precise digital values absolute EGT, scary temperatures in the 1,300s, 1,400s, 1,500s, even 1,600s Fahrenheit. Few understood what these temperatu meant, but most assumed that—as with most other temperature aviation (cylinder head temperature, turbine intake temperatur outside air temperature, oil temperature, etc.)—cooler was bett and hotter was worse.

FIGURE 2

EI's US-8 Ultimate Scanner displays absolute digital EGT information, as does JPI's EDM-700, and subsequent generations of digital engine monitors have all done the same.

WHAT EGT IS NOT

In fact, however, absolute values of EGT are not particularly int esting for a number of reasons. The most important is that *indic EGT is not a "real" temperature.* To understand what I mean by

PHOTOGRAPHY BY MIKE

e you to conduct a thought experi- Imagine that you're an EGT probe, d in an exhaust riser between 2 and 4 s from the exhaust port of a cylinder, ink about what you would see.

Figure 3 illustrates, you'd see nothing two-thirds of the time—during most intake, compression, and power es—because the exhaust valve is closed o no exhaust gas is flowing out of the st port and past the probe. During the hird of the time that the exhaust valve n, you'd see a constantly changing gas erature that starts out very hot when lve first opens but cools very rapidly as t compressed gas escapes and ds, and then ultimately is scavenged d induction air during the valve over- eriod (at the end of the exhaust stroke he beginning of the intake stroke) when ntake and exhaust valves are open taneously.

ow, all these gyrations are happening t 20 times per second, and you (the EGT probe) cannot possibly keep up with them. You wind up stabilizing at some temperature between the hottest and coolest gas temperature you see, and you dutifully report this rather arbitrary temperature to the panel-mounted instrument, where it is displayed to the pilot as a digital value accurate to 1 degree. The temperature you report to the pilot is not exhaust *gas* temperature (which is gyrating crazily 20 times a second), but rather exhaust *probe* temperature (which is stable but related to actual exhaust gas temperature in roughly the same fashion as mean sea level is to high tide).

To make matters worse, numerous factors can affect indicated EGT besides actual exhaust gas temperature. These include probe mass and construction (grounded or ungrounded), cam lobe profile, lifter leak-down rate, valve spring condition, and exhaust manifold topology, among others.

For example, the two front cylinders (No. 5 and No. 6) on the left engine of my Cessna T310R always indicate lower EGTs than the other four cylinders. The exact same phenomenon also occurs on the right engine. This is not because those front cylinders produce cooler exhaust gas than their neighbors (they don't), but because the exhaust risers for those cylinders curve aft

TURBINE INLET TEMPERATURE (TIT)

Turbocharged engines are often equipped with a turbine inlet temperature (TIT) gauge or a TIT probe connected to the aircraft's digital engine monitor. Unlike EGT, absolute values of TIT are meaningful, because the TIT probe is mounted far downstream in the exhaust system where the gas flow past the probe is steady (not pulsed) and has relatively steady temperature (not constantly fluctuating). Observance of an absolute TIT redline (typically 1,650 degrees or 1,750 degrees) is appropriate and prudent to obtain maximum useful life from the turbocharger. —*Mike Busch*

MIKE BUSCH

FIGURE 3

An EGT probe "sees" a rapidly changing gas temperature during the one-third of the time that the exhaust valve is open and nothing much during the two-thirds of the time that the exhaust valve is closed. Thus, EGT indicated by a digital cockpit gauge is not a "real" gas temperature.

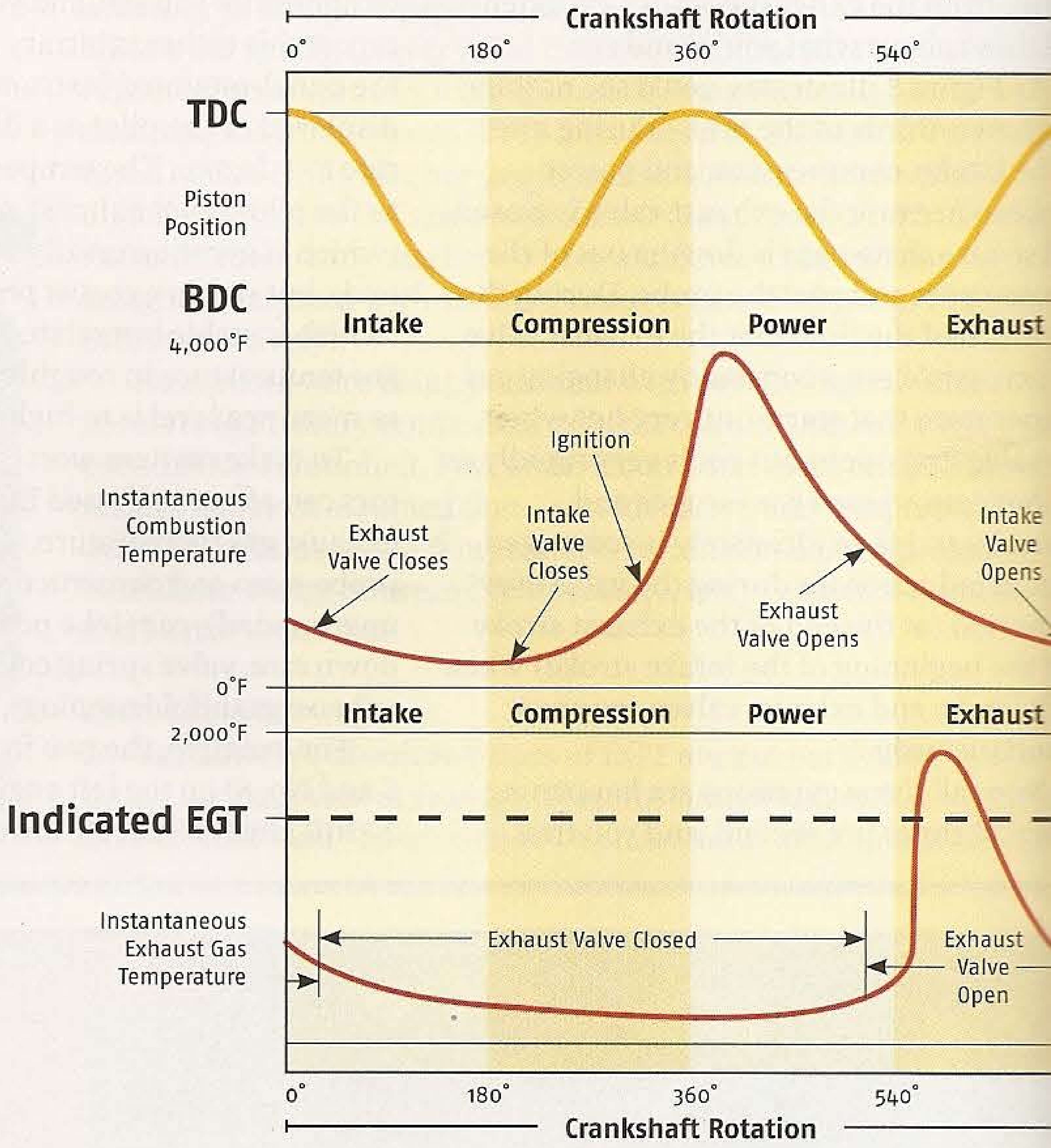
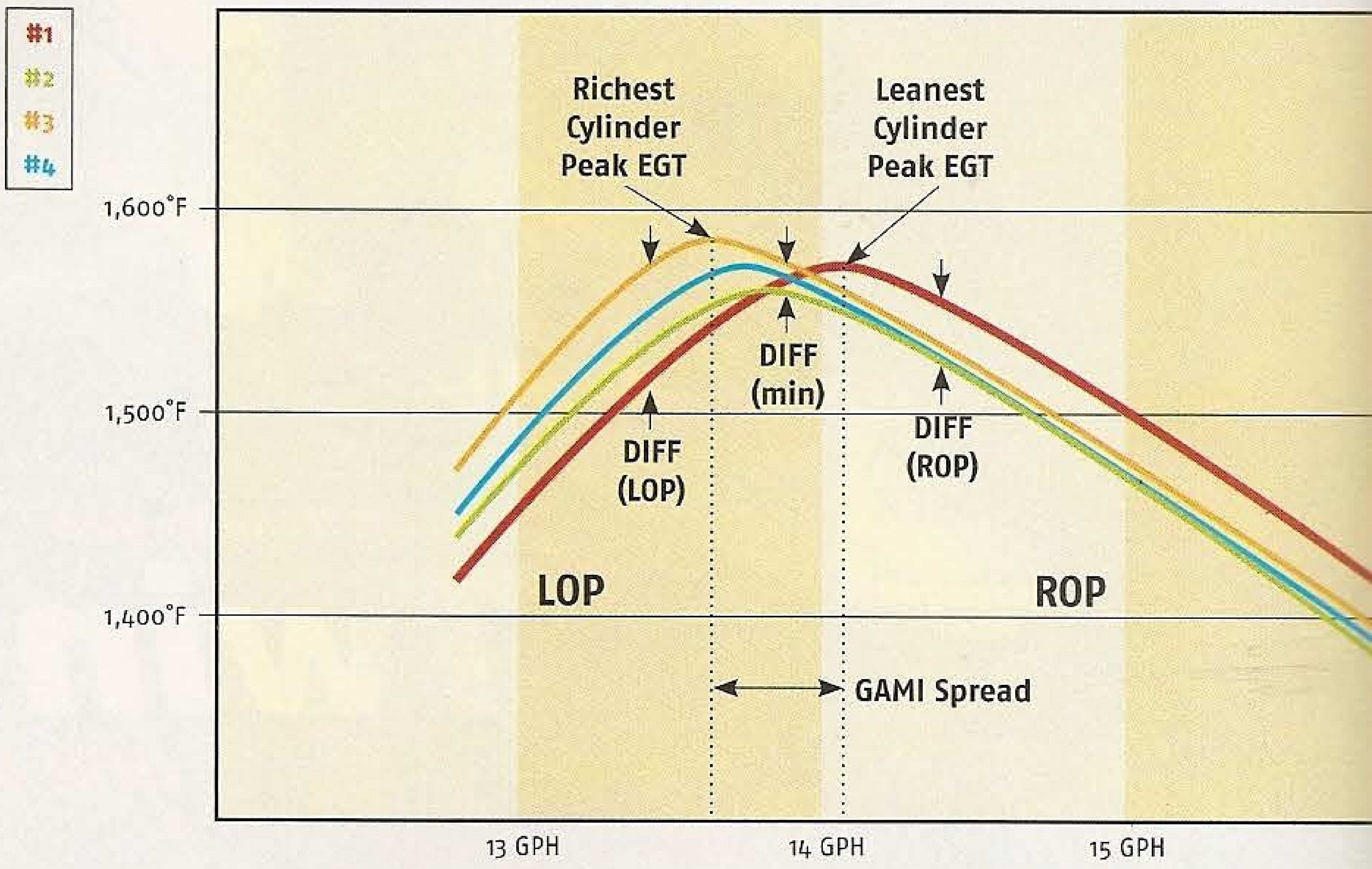


FIGURE 4

The spread between absolute EGT indications (depicted as "DIFF" on some digital engine monitors) is not important. What's important is the spread between fuel flows where the various cylinders achieve peak EGT (known as the "GAMI spread").



CHARTS COURTESY OF **MIKE BUSCH**

while the other four risers go straight down. Thus, the gas flow past the EGT probe is different for the front cylinders than for the others, and their indicated EGT is lower. This temperature anomaly is quite obvious on my digital engine monitor—and also quite meaningless.

WHAT EGT MEANS

Even if indicated EGT accurately reported actual exhaust gas temperature (which it doesn't), it's important to understand that exhaust gas temperature does not correlate with stress on the engine the way cylinder head temperature does. In fact, many things that increase engine stress (such as advanced ignition timing and high compression ratio) cause EGT to go down, while things that reduce engine stress (like retarded ignition timing and low compression ratio) cause EGT to go up.

Remember that CHT mainly reflects what's going on in the cylinder during the power stroke when the cylinder is under maximum stress from high internal temperatures and pressures, while EGT mainly reflects what's going on during the exhaust stroke after the exhaust valve opens and the cylinder is under relatively low stress.

High CHTs often indicate that the engine is under excessive stress, which is why it's so important to limit CHTs to a tolerable value (no more than 400 degrees, preferably 380 degrees or less). By contrast, high EGTs *do not* indicate that the engine is under excessive stress, but simply that a lot of energy from the fuel is being wasted out the exhaust pipe rather than being extracted in the form of mechanical energy.

For instance, a 1972 Cessna 182 with an O-470-R engine will typically have indicated EGTs that are 100 degrees hotter than those seen in a 1977 Cessna 182 with an O-470-U engine. The -R has a relatively low 7.0-to-1 compression ratio because it was certificated for 80-octane avgas, while the -U engine has a much higher 8.6-to-1 compression ratio because it was certificated for 100-octane. Because the high-compression -U engine is significantly more efficient at extracting heat energy from the fuel, it wastes less energy out the exhaust and thus its EGTs are cooler (despite the fact that the -U engine is much more highly stressed than the -R).

High EGTs do not represent a threat to cylinder longevity the way high CHTs do. Therefore, limiting EGTs in an attempt to be "kind to the engine" is simply misguided.

DIFF VERSUS GAMI SPREAD

Right behind the "high EGTs are bad" myth is the "identical EGTs are good" myth. Many pilots believe incorrectly that a flat-topped graphic engine monitor display (with all EGTs equal) is the mark of a well-balanced engine, and that unequal EGTs are a sign that something is wrong. This common misconception tends to be reinforced by digital engine monitors that display a digital "DIFF" showing the difference between the highest and lowest EGT indication.

As illustrated by the earlier anecdote about the front cylinders on my Cessna T310R, differences between absolute EGT values are both normal and benign. It is not uncommon for well-balanced fuel-injected engines to exhibit EGT spreads of 100 degrees, and carbureted engines often have spreads of 150 degrees or more. In fact, as shown in Figure 4, EGT spreads are usually smallest near or just rich of peak EGT (the worst place to operate the engine), and often significantly greater at leaner or richer mixtures (that are much kinder to the engine).

The mark of a well-balanced engine is *not* a small EGT spread ("DIFF"), but rather a small "GAMI spread"—defined as the difference in fuel flows at which the various cylinders reach peak EGT. Ideally, we would like to see this spread be no more than about 0.5 gph (or 3 pph). Experience shows that if the GAMI spread is much more than that, the engine is unlikely to run smoothly with LOP mixtures.

IT'S ALL RELATIVE

Al Hundere had it right after all: The only important thing about EGT is its *relative* value: how far below peak EGT and in which direction (e.g., 100 degrees ROP or 50 degrees LOP). *Absolute* values of EGT (e.g., 1,475 degrees) are simply not meaningful and are best ignored. There is no such thing as a maximum EGT limit or redline, and trying to keep absolute EGTs below some particular value—or even worse, leaning to a particular absolute EGT value—is simply wrongheaded. Don't do it. If you must fixate on those digital engine monitor readouts, fixate on something important, like CHT. EAA

Mike Busch, has been a pilot for 44 years, logging more than 7,000 hours. He's a certificated flight instructor and an airframe and powerplant mechanic with inspection authorization. Log in to join Mike for a webinar titled "Say No to Useless Maintenance" on November 9 at 7 p.m. CDT at *www.EAA.org/webinars*.