Exhaust Gas temperature and fuel management

Since so many operators of our engines frequently ask us about the use of an exhaust gas temperature with our powerplants, perhaps we should examine the system, and also see how it relates to fuel management.

One of the better publications describing the EGT that we have seen was put out by Alcor Inc., P. O. Box 792222 of San Antonio, Texas 78279-2222. This excellent booklet is titled, "EGT and Combustion Analysis In A Nutshell", and is available free to interested operators.

An EGT system is not a complex or expensive item to install. The more economical kit consists basically of the gage, wiring, and probe (see illustration). The system generates its own electricity to operate the instrument.

INSTALLATION INFORMATION

The mechanic must carefully follow the installation instructions concerning placing the probe in the exhaust stack. If it is closer than 1 ½ inches to the cylinder head, probe life will be limited, or if too far down toward the end of the exhaust stack, the response on the gage will be slow. Should there be doubt concerning in which stack a single probe is to be installed, that information may be available from the airframe dealer's service department. The operator might desire the more expensive installation of probes in all cylinders, therefore the accompanying gage will generally have a selector switch for individual readings on all cylinder exhaust stacks. Again, it is most important that the installation instructions are carefully followed in order to get reliable readings.

INTERPRETING THE SYSTEM

Most of the EGT manufacturers have standardized on gage increment markings of 25ø F (see illustration). A few EGT manufacturers will go further and show the temperature range on the gage as 1200o F to 1700o F.

The simple gage shown in the illustration is quite satisfactory for the less complex engines. An advantage of the EGT over the cylinder head temperature gage is one of an almost immediate response to manual movement of the mixture control, as long as it is not a rapid movement of the control. Remember that the peak or point of maximum needle deflection of the EGT gage is the basic reference for fuel management. If an operator has experimented with the EGT at the engine manufacturer's recommended cruise power, he observes that gradual leaning does result in peak EGT. The location of peak EGT on the gage will also vary with different power settings, changes in altitude, and change in ambient temperature.

From peak EGT, either increasing or decreasing the fuel flow causes a decrease in EGT. When richer than peak EGT cooling occurs because there is excess fuel, and when leaner than peak, cooling occurs because there is excess air.

Peak EGT with a float-type carbureted engine is frequently a vague point because of less efficient distribution (than fuel injection) to the individual cylinders by this type of metering device. As a result, float-type carbureted engines tend to operate smoother at +25o to +50o F on the rich side of peak EGT. Whereas, the fuel injected engines at 250 H.P. and higher will provide a more precise peak, and therefore the EGT system is likewise a more precise method of fuel management with fuel injection.

DEFINITION OF PEAK EGT

A simple definition of peak EGT is given us by engineering as - the chemically correct mixture of fuel and air which gives 100% utilization of all the fuel and all the air. Remember, we said earlier that at mixtures leaner than peak EGT there is excess air, and at richer mixtures, excess fuel. Operation at peak EGT, particularly on long flights, can be an advantage not only for purposes of increased range, but there is less likelihood of spark plug fouling as well.

Don't be surprised to see variations in temperature between individual cylinders where there is a probe for every cylinder. It is fairly typical to see an average 100o F variation with fuel injection, and as much as 200o F variation with a float-type carburetor. The latter (carburetor) variation tends to be greater because fuel/air distribution is not as good as with fuel injection. In cold outside air temperature flight conditions, the mixture distribution is poorer for both fuel injected and carbureted engines. However, with the float-type carburetor operating in below freezing ambient temperatures, the fuel/air distribution is definitely worsened, resulting in noticeable variations in temperature between individual exhaust stacks.

It is also important to understand that leaning to roughness at the engine manufacturers recommended cruise power is not an indication of detonation, but indicates normal characteristics of distribution to the individual cylinders. The roughness indicates that the leanest cylinder has become so lean it is beginning to miss. This is typical of an engine with a float-type carburetor. Damage to an engine from leaning does not occur at the manufacturers recommended cruise power, but takes place at higher than cruise power.

As far as the pilot is concerned, operating on the lean side of peak EGT can only be accomplished with fuel injected engines of at least 250 HP or higher because the fuel flows in the lower horsepower engines are so small. It isn't possible with float type carburetors because of the fuel/air distribution problem. In any case, **leaning past the peak is not recommended**.

LIMITATIONS OF POWER AT PEAK EGT

Textron Lycoming allows leaning to peak EGT at 75% power and below on our direct drive normally aspirated engines. We limit operation at peak EGT on our geared, supercharged powerplants at 65% power or below. With Lycoming turbocharged engines, where the EGT gage is used to interpret turbine inlet temperature (TIT), the maximum allowable TIT specified in the POH should not be exceeded when attempting to find a peak temperature by manual leaning. Where a cylinder head temperature is also available, the operator should always cross-check the head temperature as a routine procedure when leaning, and remember that whenever CHT reaches the maximum before reaching peak EGT, then CHT rather than EGT should dictate the limit of allowable leaning.

BEST ECONOMY MIXTURE

Best Economy Mixture as it relates to the EGT system begins at peak. For all practical purposes with Lycoming engines, peak EGT is right at the edge of Best Economy mixture, and is our only practical point of reference in the Best Economy Mixture range. At the manufacturers recommended cruise power, peak EGT causes a slight loss of horsepower usually reflected in two or three miles per hour of airspeed. If the pilot attempts to go leaner than peak EGT (with fuel injection only), the power decreases rapidly as fuel flow decreases.

BEST POWER MIXTURE

Best Power Mixture, or sometimes termed Maximum Power Range, as depicted on the EGT gage, is in the range of plus 100o F on the rich side of peak. Best Power Mixture will provide fastest indicated airspeed for a cruise power setting, although it is generally not considered a practical economic mixture for cruise purposes. However, Best Power Mixture generally provides a safe amount of fuel for a power setting higher than the engine manufacturers recommended cruise, except that needed for takeoff power.

Again we repeat that maximum leaning (peak EGT) does not damage an engine at the engine manufacturers recommended cruise power. Damage is caused by maximum leaning at higher than recommended cruise power where the manuals do not spell it out or allow it, and when the aircraft does not have a complete set of reliable engine instruments to protect the powerplants. Excessive leaning under the latter high power conditions can cause detonation and/or preignition and possible engine failure.

If we were to sum up the major advantages of an EGT to the operator, they are as follows:

1. Saves fuel - an economy aid.

2. Aids proper mixture control - more precise fuel management.

3. s increase range.

4. Detects some types of engine troubles.

5. Aids peak engine performance at cruise.

6. s prevent spark plug fouling.

7. Fits any General Aviation piston aircraft engine.

Although use of the EGT has the advantages listed above, from a pilot’s point of view there are also some possible disadvantages. Poor mixture distribution to the cylinders (particularly in carbureted engines) is the primary reason for these disadvantages. The

EGT probe is to be installed in the leanest cylinder, but this changes with altitude and power setting, therefore making it very difficult, or perhaps impossible, to choose a best cylinder for probe installation. Without an EGT installation the pilot can easily lean using the leanest cylinder of a carbureted engine by simply leaning to find engine roughness from the first indication of "lean misfire", and then richening the mixture to smooth engine operation.

The pilot must also realize that even with a fuel injected engine there will be variations in fuel flow. Utilizing an EGT with probes in each exhaust stack (sometimes called a combustion analyzer) will show these variations. Trying to interpret the variations in temperature shown for each cylinder has caused some pilots to suspect problems with there engine when it has been operating normally. Sometimes too much knowledge can be a problem.

Finally, the EGT system must be in perfect working order to give accurate readings. The probes in the exhaust system will deteriorate with age and continuous use. This often causes the gage to read a temperature that is not accurate, and therefore a peak reading that is not reached soon enough. This results in overleaning to the lean side of peak where operation is not recommended. Frequent maintenance to insure that temperature probes are in good condition will reduce the possibility of inaccuracies, but the pilot cannot determine the accuracy of this rather critical reading during operation.

The exhaust gas temperature system, when well maintained and thoroughly understood, can be an aid in proper leaning at cruise power with fuel injected powerplants. It is hoped that this information will the operators of Lycoming engines achieve the best possible engine efficiency through use of the EGT system.