# Octane Requirement and Your Experimental Airplane

*Robert H. Yeakey P.E.*
*7921 Bellewood*
*Dallas Texas 74238*
*(214) 348 2947*

You honestly believe your airplane needs the octane number fuel that you see on the engine data plate-right-wrong! The first and lower number on the Lycoming 180 hp is based on 100LL because that is the only suitable gas available. 91 octane is the correct and actual requirement for this particular engine. Because of unavailability 91/96 is not on the data plate.

As Technical Service Engineer for Humble Oil several years ago my duties included dealing with the situation created by trends toward ever higher compression ratios and combustion temperatures. Golden Esso Extra and Gulf Crest high octane (over 100 MON) fuels resulted from these formulation studies.

## OCTANE DETERMINATION

How is fuel octane measured? The ASTM (American Society for Testing Materials) test is accepted throughout the world. A standard ASTM single cylinder CFR (Cooperative Fuel Research) variable compression engine is run on isooctane/heptane blended samples to establish incipient "knock" guidelines. One hundred percent isooctane produces an anti-knock quality of 100. A eighty eight percent isooctane, twelve percent heptane mixture produces an 88 octane anti knock quality and so on. Test and commercial fuels are rated against this standard measurement technique. At Southwest Research Institute we ran a test fuel in a flat head Ford V8. Running on a 70 octane blend test fuel the engine had an incipient knock. So any commercial gasoline of 70 octane would take care of this car's needs. Incidently, octane requirements over 100 are possible to be measured by the addition of TEL (tetraethyl lead) to pure isooctane. Above 100 these values are usually referred to as performance numbers (PN).

We have mentioned that 100LL is not the true engine requirement for the Lycoming 180 hp engine. Is the Lycoming 180 91 octane specification required all the time according to your engine manual? No-not true! Only once in a great while is 91 octane required. In one test I recall, Al Hundere, President of Alcor, tried to make the 180 knock using auto leaded regular (at 6,500 MSL, 40 degree F.) but failed.

## REAL OCTANE FACTORS

Dallas is above sea level; that computes to reduced air density and octane need. We also have some humidity that also reduces the air/fuel charge and the octane requirement. The OAT is usually below 60 degrees F. which cuts the air/fuel weight entering the engine. At WOT standard procedure is to run full rich. This also reduces the requirement by cooling the combustion. Thus, it is quite unusual for the 180 to need fuel of 91 octane motor method.

## PUMP OCTANE

Engines sometimes read differently than the CFR test engine, falling somewhere between the motor (MON) and the research (RON) method numbers. This difference is called the spread, usually 6 to 8 numbers. The number seen on pumps is an average of both method numbers. To get the motor method just subtract 4 numbers from the (R+ N) /2 pump number. Prior to EPA action gasoline was advertised heavily using the larger, RON number.

## KNOCK MECHANISM

The actual detonation is an instantaneous combustion of the last portion of the air/fuel charge. When the spark plug ignites the mixture, the first 80 to 90 percent burns smoothly and the cylinder presseure rises in a nice pressure versus crank angle curve but as the flame front approaches the far reaches of the chamber the high temperature finishes off the remaining mixture with a bang. It is quite audible on most engines except the ones in aircraft. Knock causes overheating, quickly leading to holed pistons, and more. Liquid cooled engines are slightly more tolerant, having additional capability to remove excess heat.

## ENGINE DESIGN FACTORS

Design of the combustion chamber influences the octane requirement. The following factors have significant effects: 1) distance from the plug to the most distant part of the cylinder 2) cylinder and exhaust valve temperatures 3) size of the combustion chamber quench area 4) ignition timing; the fixed timing of a magneto makes a higher octane specification necessary, electronic ignition with a knock sensor will largely eliminate this factor 5) coolant type-best is water with a rust inhibitor-next a ethylene glycol mixture, about 50/50-worst is air cooling 6) deposits which may induce preignition and 7) compression ratio, either designed or due to carbon buildup. Compression ratio also affects the requirement, but certainly, contrary to FAA preachments, is only one factor and not necessarily the most important.

There are two design features that cause many aircraft engines to demand gasoline of higher than normal octane:

Almost from the beginning, the aircraft engine was air cooled. In small general aviation aircraft proper engine speed for substantial power output was ignored to accommodate the .8 Mach maximum propeller tip speed. This kept the rpm slowed down, to get by without the use of expensive and weight increasing reduction gearing. Looking at the engine comparisons table, the result of the design direction was a much larger engine with high octane requirement. Basically this octane was required - a worst condition basis - because of marginal air cooling and the large piston diameter. For example, the Lycoming 150 and 160 hp engines have 5 1/8 inch diameter pistons. The efficient car engines - the last four in the table - have water cooling and pistons less than 3 1/2 inches in diameter.

### *ENGINE REQUIREMENTS*

| ENGINE | HP | RPM | MON | CR | HP/IN$^3$ |
|---|---|---|---|---|---|
| Lyc O-360 | 180 | 2750 | 91 | 8.5:1 | .50 |
| Lyc O-320 | 160 | 2750 | 91 | 8.5:1 | .50 |
| Lyc O-320 | 150 | 2750 | 80 | 7.0:1 | .468 |
| VW Quantum inline 4 110 in$^3$ | 88 | 5500 | 83 | 9.0:1 | .80 |
| Nissan Maxima inline 6 180 in$^3$ | 120 | 5200 | 83 | 8.9:1 | .822 |
| Nissan V6 180 in$^3$ | 152 | 5200 | 83 | 8.9:1 | .844 |
| Buick V6 225 in$^3$ | 160 | 4400 | 85 | 8.5:1 | .71 |

One other factor working against performance is the magneto. The certified magneto ignition system causes a higher specified octane requirement. A system employing a knock sensor would give a far more economical solution.

The use of a more sophisticated and up to date ignition system together with lower octane number than the current ultra conservative one that you now see on the data plate would achieve a real reduction in fuel cost and overall operating expense.

There is no reason why super unleaded car fuel should not fully satisfy the current Lycoming 160 and 180 hp engines.

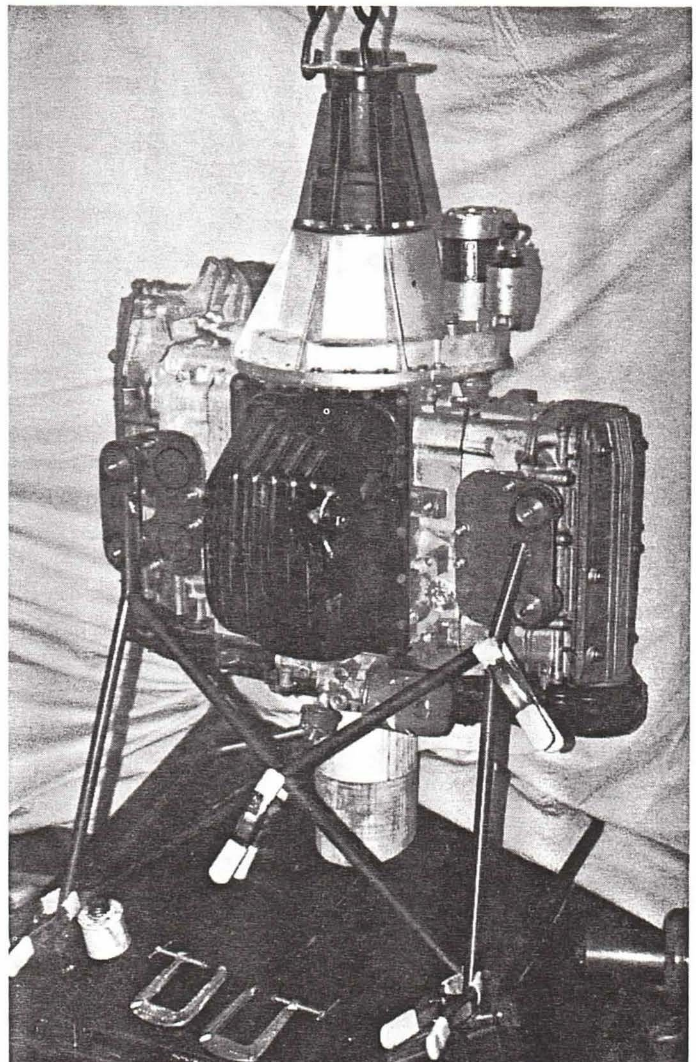
It would seem that design progress was made only when EAA lit a fire under the two aircraft engine manufacturers. Continental Teledyne brought out a water cooled version of the old O-200 and O-300 engines. It likely would never have happened without Dave Blanton's early experimentation program. His V6 Ford powered C-175 flies on 6.8 gallons per hour at cruise on super unleaded car gas! This V6 has a simple belt reduction propeller drive that slows the prop down and lets the engine work. The cost of this and other auto conversions make them very attractive.

## *CONCLUSIONS*

A. Regular auto gas blended 66 percent with 34 percent 100LL will perfectly satisfy the current existing Lycoming 160 and 180 hp engine versions. This ratio also cuts the lead concentration to the optimum value, about .65 cc/gallon, thus beneficial valve lubrication is maintained with reduced lead fouling problems.

B. Auto gas alone will work beautifully in any 7.00:1 compression ratio aircraft engine. These are the most numerous in the general aviation fleet.

C. A change to electronic ignition is legal for experimental aircraft and will reduce the engine octane requirement enough to permit auto gas in most any experimental airplane.



**Ross Aero engine mount fabrication method: 1) firewall attach points are defined on bottom plate 2) engine pulley/centerline is placed on located wood plug and steadied by hoist at prop flange 3) plumb measurements are taken to define thrust line offsets and 4) engine mount is fabricated. Yeakey's T18 Subaru XT6 mount is shown here.**