NOTAP FROM API OPERATIONS - ENGINE MANAGEMENT
September 1980.

While we are beginning to melt off our load of financial ice and have recently climbed painfully to a better revenue-altitude, Neil has emphasized that we are in no position to entertain major engine expense or loss of revenue due to any serious AOG problem. Recently we had a round of this with the Mooney's exhaust system, which had to be replaced. While the exact cause of the failure is not known, I have noticed some ill-informed or fairly casual flying habits which might even now be contributing to further trouble with our engines. Some thoughts:

A. AIRSPEED FOR COOLING

AVOID GRINDING ALONG WITH SIGNIFICANT POWER AT A LOW AIRSPEED!

BE VERY CAREFUL TO SEE THAT THE MOONEY'S COWL FLAPS ARE OPEN DURING ANY LOW-AIRSPEED, HIGH POWER MANEUVER. (LIKEWISE, DON'T FORGET TO OPEN THEM ON THE GROUND).

Airplane engine cooling systems are rather critical. Prolonged maximum rate or angle climbs, prolonged use of go-around power while dragging along with the wheels down, or excessive slow-flying high on the back side of the power curve may allow the aircooled parts to reach dangerous temperatures. DON'T MURDER THE ENGINE THIS WAY. In our speed range, heat transfer is roughly proportional to airspeed, and therefore speed has an enormous effect on temperature. USE MAXIMUM PERFORMANCE POWER AND AIRSPEEDS WHENEVER YOU HAVE TO, BUT KEEP SUCH USAGE BRIEF AND AS SOON AS POSSIBLE, GET SOME AIRSPEED. In normal climb with the Mooney, use 26"/2600 rpm, mixture rich, and the higher of the recommended en-route climb speeds whenever possible (115 mph).

B. LEANING PRECAUTIONS

ALWAYS LEAN IN CRUISE. DON'T WASTE GAS AND FOUL THE PLUGS BY FORGETTING TO LEAN, EVEN ON SHORT HOPS.

LEAN THE ENGINE CAREFULLY! ALWAYS CHECK FULL RICH (OR LEANED AS REQUIRED FOR T.O. AT HIGH AIRPORTS) BEFORE TAKEOFF! <u>IN CLIMB</u>, ALWAYS SET FULL RICH WHEN INCREASING POWER, THEN LEAN IF NECESSARY FOR SMOOTH OPERATION, STAYING AT LEAST 125 DEGREES DOWN ON THE RICH SIDE FROM PEAK.

WHEN LEANING IN <u>CRUISE</u> (%BHP < 75%) SET EGT JUST SLIGHTLY ON THE RICH SIDE OF PEAK!

WATCH POWER AND MIXTURE SETTINGS WHEN DESCENDING - KEEP POWER FROM CREEPING UP AND MIXTURE FROM RUNNING LEAN.

Our mechanic has suggested that we might avoid future valve and exhaust system trouble with the Mooney by using the best-power settings (100 degrees rich). The Mooney factory does not concur, saying that this only wastes gas (1.5 gph) and shortens range (by 1 hr). The factory recommends operation by the book (25 degrees down from peak on the rich side) and further, says that operation right at peak (%BHP < 75%) is OK. Our considered opinion is that the factory recommendation should be followed, and overheating countered by attention to the airspeed, as outlined above.

Since the EGT peak is somewhat broad and hard to determine at times, I recommend enriching to get a small but definite drop, i.e., the recommended 25 degrees, and then running it right there!

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172 should likewise be leaned carefully, even for short .ps, especially if 100LL is aboard. Leaning while taxiing .d waiting on the ground may also be helpful (but don't forget to enrich again before t.o.!). Plug fouling by 100LL calls for aggressive leaning to burn the deposits off, and in ordinary cruise, the mixture should always be leaned carefully, close to peak. With 80, things aren't so critical, but you should still lean when leaving the traffic area to go somewhere.

Setting the mixture accurately isn't terribly important whe you are first starting out on your trip and you're still i the vicinity of the airport traffic area. DON'T FLY WIT YOUR HEAD BURIED IN THE COCKPIT WHILE YOU FUSS WITH TH MIXTURE! Once at initial cruise altitude, lean by ear an keep your eyes elsewhere. Slowly pull (or unscrew) the kno until the engine sound changes and you feel a slight powe loss, then shove it in (slowly and smoothly) half an inch (o a couple of turns) to where the engine runs comfortably Refine the setting later in cruise after cleaning up th cockpit and settling down. Make the adjustment with the EG in stages, scanning the instrument 10 seconds later afte making the change to see what you accomplished each time. THEN LEAVE IT ALONE unless you're changing power or altitude. You can test the setting now and then by leaning or enriching slightly and noting the needle movement, but don't fiddle with it or stare at the instrument and neglect your scan. Generally speaking, you should be doing something else while waiting for the gauge response.

When making a long, slow descent, check the power setting and push the mixture knob in occasionally to make sure that you stay within the power percentage you want, keeping the mixture on the rich side. Of course, be absolutely sure that the mixture is set appropriately rich (and fuel tank on fullest) before you begin an approach, and check mixture rich before starting a go-around or a climb.

Incidentally, never skimp on takeoff or performance-climb power thinking that you are doing the engine a favor. You're not -- and by not getting safe altitude promptly, you aren't doing yourself a favor either! Always set the mixture rich (or to the appropriate best-power setting if necessary to lean for high altitude -- out West, for example) and check the setting as you roll into position. Then apply takeoff power. Full throttle at takeoff or other high-power, low-airspeed occasions is specifically recommended, since it typically brings extra jets in the carburetor into action which further enrich the mixture for improved engine cooling.

(On the other hand, cruising with the throttle perpetually firewalled like they do out West, is definitely not a good idea, unless you happen to be at an altitude where this can't result in %BHP over 75%.)

C. ENGINE POWER SETTINGS

CHECK YOUR POWER SETTINGS AGAINST THE BOOK: FLY AT SOME KNOWN CONDITION. KNOW YOUR FUEL CONSUMPTION AND RANGE.

KEEP THE POWER WITHIN THE RATED LIMITS; MAKE CHANGES SMOOTHLY. MAKE ANY LARGE POWER-REDUCTIONS IN STAGES TO AVOID SHOCK COOLING AND OTHER PROBLEMS.

While they will tolerate higher power settings for short times, our kind of aircraft engines are rated at 75% max BHP at cruise in order to hold down the repetitive pounding and stretching of the engine parts to a tolerable level over the normal engine life. The max. continuous power setting limit also helps to keep engine temperatures within bounds. The engines work pretty hard -- they can run at 65% or 75% for hours on end, and do this rather close to the limits imposed by the materials and the cooling. By way of contrast, an automobile engine, made of nice solid cast iron and bathed in constant temperature water, typically loafs along at only 12% (average) of its full power.

By all means stay within the rpm limits. The rpm redline on the aircraft engine is there to limit the violence of the rapidly reversing piston and rod accelerations, the speed of piston travel, and the amount of centrifugal force on crankshaft and prop. Most particularly, it is there to avoid destructive mechanical resonances lurking in mounts, crankshaft, and prop at certain rpms outside the designated operating range. With the 172, it is relatively easy to exceed redline in a dive. Don't do it!

With the Mooney, don't let it run in the restricted range without the required minimum manifold pressure! I have seen some members do just this! Although the vibration is horrendous, it will descend legally at 17"/1700 if you really want to run it there. Watch out for prop windmilling: don't

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Please see page 6-4 of the 172 manual (or pp. 5-20 through 5-35 of the Mooney manual). There you will see power, speed, and endurance figures for various rpms and altitudes. The column %BHP shows how hard the engine is working as a percent of full rated power.

(BHP is brake horsepower, an antique engineering term meaning effective power available at the propeller shaft. In the Mooney book it's mislabelled "%BPH.")

STUDY THE MANUAL MATERIAL AND KEEP THE TABLES HANDY FOR COCKPIT REFERENCE. For economy and less noise, use the 65% (or smaller) power settings Any of the rpm and manifold pressure combinations listed can be used, provided that the engine runs smoothly. There is nothing magic about "square" settings (e.g. 23" and 2300, 24" and 2400, etc.). While the lower rpms save engine wear (as well as tach time) it seems best to run the Mooney at the higher rpms, since the lower ones obviously begin to excite the wicked resonance lurking down there in the rpm restriction area.

Running the 172 engine isn't nearly as critical, but there are a few things to think about. Note that for a fixed-pitch prop the output power varies roughly as the square of the rpm, and that it decreases slowly at a given rpm with altitude (the prop encounters less air resistance at altitude, therefore to turn it at the same rpm requires less power). Note also that the maximum power obtainable is limited by the amount of air the engine can gulp down at a given altitude and the maximum rpms allowed. (The same conditions affect an engine driving a constant-speed prop, as can be seen by studying the manifold pressures corresponding to given rpm and the %BHP settings for various altitudes.)

During climb and descent in the 172, changing airspeeds have a definite effect on rpm and hence on total engine power output via the number of explosions per second, but in terms of actual strain on the engine, the effect of power ariations due to airspeed changes is small. The throttle etting vs. altitude and rpm is much more important, since it governs how big an explosion you get on each firing. The airspeed primarily affects the cooling, as described above.

The 172's engine, for example, is working hard with throttle wide open at the start of the takeoff roll, but it typically turns up only 2300 rpm at the zero initial airspeed, and thus puts out considerably less power than it does later on after the airspeed is up and the prop can turn faster. It's still under strain, however, struggling to turn at the lower rpms with the throttle wide open.

THE INITIAL MAX RPM IS SOMETHING TO CHECK, BY THE WAY, ON EACH TAKEOFF IN ANY AIRPLANE. In the 172, 50 rpm low is a loss of 4% of the total power, or a loss of at least 15% in the critical margin of excess-power available at sea level to make the airplane take off and climb! This margin decreases with altitude, of course, making rpm loss even more critical. Keep an eye on the initial takeoff rpm and compare it to what you have come to expect. (Actual takeoff rpm will vary with temperature humidity and altitude, as well as engine condition.) Any unexpected fall-off here, or any unusual sound or feel is reason to abort!

(But first check the carb heat and check ignition on "Both!" Recently we had an incident where the weight of the keys on a key ring turned the 172 ignition switch enough to drop out of "Both." on a takeoff from Rockland, Maine.

With a constant speed prop, the rpm is established by the prop governor, so one looks at the intake manifold pressure as well as the rpm to see how the engine is doing, and again compares the sound and feel of the engine with what is ected.

ing takeoff, go-around, climb, or cruise with a constant speed prop, RUNNING AT TOO HIGH A THROTTLE SETTING FOR THE RPM IS VERY BAD! With the engine running under-speed for a given power output, the repetitive explosions are both too strong and are somewhat bottled-up, subjecting the cylinders, pistons, and crankshaft to severe and prolonged strain on each successive burp.

Bear in mind what is actually going on inside! The engine, made of soft, relatively limber aluminum pot-metal and stiff, unyielding steel, actually throbs in size with each explosion, stretching and releasing the cylinders, attachment bolts, etc. All the active parts suffer rapid cyclic deflections. Temperature builds up from exhaust heat and friction. These effects bring about pronounced changes in parts fits and clearances, since aluminum expands greatly in the heat, its thermal expansion being much higher than that of steel. What's worse, since the mechanical ensemble of bearings, crankshaft, prop, and mounts are all limber and light-weight, the whole thing wiggles and shimmys with all kinds of relatively low-frequency resonances which can raise hell if they become unduly excited. Despite the best efforts of the engineers to suppress or shift them, these resonances are often perilously close to the operating range, and are just waiting to pop up under the right conditions.

Even so, an aircooled aluminum engine really doesn't suffer too much when putting out full power for just a short time. Most engine failures occur not at full power, but on first reduction after takeoff. The heavily loaded parts may experience forces from transient resonances briefly excited by the change in power or rpm. This can cause real trouble -- the Mooney manual specifically warns against exciting these resonances by sudden power changes! Also, with less centrifugal force and less heat, the distended parts, which have just accommodated themselves to full power conditions, begin to contract and rub together differently while still under heavy load. THIS IS WHY YOU MUST ALWAYS REDUCE T.O. POWER SLOWLY AND CAREFULLY -- AFTER GETTING A SAFE PATTERN ALTITUDE -- WITH THROTTLE AND PROP CONTROLS OPERATED SMOOTHLY AND IN THE CORRECT SEQUENCE EVERY TIME!

Also, while the engine can be run for a short time at high powers, and indefinitely at any of the approved cruise power and mixture settings, shock-cooling the engine or changing power loading suddenly is a bad idea at any time. Even if nothing happens immediately, violence has been done. Eventually, dangerous and expensive problems appear, such as cracked cylinder heads, cracked rings, or premature loss of compression. These are all avoidable or at least postponable with a more intelligent management of the engine. PLAN POWER CHANGES AHEAD OF TIME AND EXECUTE THEM SLOWLY, IN STAGES, IF NECESSARY!

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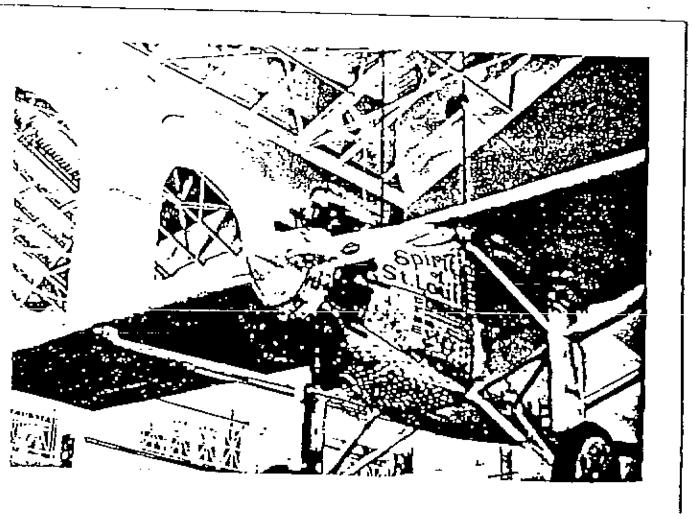
If we use good technique with airspeed, mixture, and power settings, the engines will benefit greatly, and so will we.

NR 9/80



...Probably knew how to take care of his engine.