TORNADO ALLEY TURBO, INC.

OPERATING THE TURBONORMALIZED IO-520/550

Suggestions Concerning the Operation of the Turbonormalized (TN) IO-520/550

Startup, Taxi, and Runup:

Startup, taxi, and runup are normal, except for the following considerations:

1) Consider aggressive leaning during taxi and ground operations. The concern here is to make sure that the mixture is returned to the appropriate rich position, prior to takeoff. If you routinely lean in a brutal manner on the ground, to the point that the engine will ‘stumble' if you advance the throttle, this protects against an inadvertent attempt at a takeoff with less than an appropriately rich mixture.

2) If the mixture is lean during the mag check, you should expect a larger than normal drop in RPM. Any significant difference between the LEFT/RIGHT magnetos should be investigated by a mechanic. Remember, lean of peak cruise operations require an aggressively well maintained ignition system, including the magnetos, harness, and plugs. It is especially important that the magneto timing be accurately set to the book spec. Any retarded timing will cause higher than normal EGTs and TIT.

Takeoff:

Follow the POH supplement in this regard. Consider the following:

1) The engine's fuel flow is set rather rich to afford adequate fuel flow for high altitude climb cooling. Normally, at full rich, the TIT will be at or below 1200F on the TIT, during a full power takeoff. For shorter field operations, this is richer than necessary and is obtained at the expense of the loss in some horsepower. Therefore, for short field operations, leaning the mixture on takeoff, by reference to the TIT is appropriate. A suggested initial TIT would be from 1310 to 1380 F. Depending upon the outside air temperature, this will be obtained with a fuel flow from as little as 24 gph (hot day) to as much as 30 gph on a cold day.

2) After the landing gear is retracted and the initial obstacles are cleared, the TIT should be promptly re-leaned to the target TIT, as described under "Climbs", below.

3) Engines equipped with a two speed fuel boost pump (OFF / LOW / HIGH) should use normally use the LOW position during takeoff and climb to assist in preventing the occasional vapor lock which, typically occur between 8000' and 15,000'. DO NOT USE the HIGH/ON position during takeoff unless there is a failure of the engine driven fuel pump. Engines with only a single speed boost pump should not use that pump during takeoff, except during a failure of the engine driven fuel pump.

NOTE: If the oil temperature is not in the middle of the green arc, the MP may momentarily exceed the redline on the manifold pressure gage during takeoff. This is fairly normal with turbocharged engines in the general aviation fleet. If you observe that the MP exceeds the redline by more than approximately 2", you should promptly reduce the throttle so that the MP is at the redline. The engine is protected by a mechanical "pop-off" valve in the event of a serious over pressure from the turbocharger.

Climbs:

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1) In general, use full throttle and 2500 RPM during the climb. Cowl Flaps OPEN. Unless the engine is overboosting for some reason, DO NOT USE PARTIAL THROTTLE POSITIONS DURING THE CLIMB. This does not help the engine, it prolongs the climb, and it may actually result in higher CHTs during the climb than using Wide Open Throttle (WOT).

2) The mixture should be adjusted by reference to the TIT, according to the following schedule:

A) Sea level to 10,000 feet:

1) Use 115 to 120KIAS and

2) A target TIT of 1280 to 1300F.

B) 10,000 feet: to 17,000':

1) Use 115 KIAS, and

2) A target TIT of 1260 to 1280F.

C) 17,000' and above;

1) Use WOT (Wide Open Throttle) and 2600 RPM;

2) Use a target TIT of 1240 to 1260 F;

3) Use 105 to 110KIAS, or more as desired for an appropriate rate of climb.

D) NOTE: While using the "Target TIT" during the climb, you should monitor the cylinder head temperatures. If any CHT goes above 380F, you should promptly add fuel flow in order to reduce the target TIT by 10 degrees F. If the CHT continues to increase, you should continue to increase the fuel flow so as to further reduce the target TIT setting until the CHT stabilizes and returns to a value below 410F, and preferably below 380F.

E) NOTE: The "Target TIT" values listed above are just that, *target* values. Experience has shown that most of the turbonormalized IO-520/550 engines can use those values for the Target TIT. However, there are variations in calibration of the TIT gages. There are further variations due to such unobvious things as magneto timing, all of which can alter the appropriate Target TIT. Thus, it is important to monitor the CHTs during the climb, as a method of confirming that the Target TIT is appropriate. If the CHTs are too high you should adjust the Target TIT as described in the previous note, until the matter can be further investigated. In our experience, the climb "target" TIT values tend to fall in a fairly close group of values, as described above, without significant variation from engine to engine. However, the absolute value of the typical cruise TITs tend to show substantial variation from one engine to another. Again, this does not represent real variations in fuel/air ratios, but, unless extreme, these variations represent variations in probe placements, wiring, minor electrical ground loops, and related problems.

F) NOTE: There are very few areas of aircraft operation where a few degrees of difference in temperature make a significant difference in the proper operation of the engine. However, the "Target TIT" method of climb mixture control is one instance where deviation by as little as 15 or 20 degrees (F) in the Target TIT can cause CHTs to rise to levels into the low 410 to 420 F range, which is not desirable for continuous or routine climb operations. In our experience, using the "Target TIT" method of mixture control during the climb works extremely well, is very simple, and is superior to any other method. All other methods are confounded by seasonal and day to day changes in outside air temperatures (OAT). Pay attention to the target TIT during the climb!!!

G) NOTE: You may observe that use of the "Target TIT" method of climb mixture control results in significantly different fuel flows from day to day. This difference is purely a function of the effect of the outside air temperature upon the fuel/air ratio of the engine. Thus, on hot days, with the engine properly leaned to the appropriate "Target TIT", the fuel flow may be three to six gallons/hour less than the fuel flow observed on a very cold day, when the same "Target TIT" is used during the climb. This is normal, desirable, and provides for enhanced performance by avoiding unnecessarily rich mixtures on hot days and by avoiding excessively high CHTs on cold days due to the climb mixture being too lean because of increased air density. Use of the "Target TIT" method of mixture control actually simplifies climb mixture management, by avoiding the necessity to constantly refer to different charts and graphs to determine the correct fuel flow as a function of OAT and other factors.

H) NOTE: Sometimes vapor will form in the fuel system during a climb. This happens even with normally aspirated IO-550 engines, on a routine basis. Should you notice that the TIT is rising unexpectedly, or that the fuel flow needle is "wiggling" (or for any other reason you have an inadequate fuel flow) you should assume you have an actual or incipient vapor lock. In this instance, turn the boost pump to ON/HIGH (depending upon the particular system) and then re-lean the mixture manually to achieve the original "Target TIT." If, for any reason, you are unable to obtain adequate fuel flow, do not hesitate to use the LOW or even the HIGH boost pump position. If using the HIGH boost pump position, you may have to manually lean the mixture to prevent the engine from "stumbling" from operating too rich. After the climb is complete, you should return the boost pump to the OFF or LOW position, and relean the mixture for cruise as described elsewhere.

I) CAUTION: Use of the HIGH or ON positions of the boost pump during takeoff can cause an excessively rich mixture and adversely affect takeoff performance. The HIGH/ON boost pump positions should not be selected during takeoff unless one believes there is a loss of engine driven fuel pump fuel pressure.

Lean of Peak Cruise Operation of The Turbonormalized (TN)IO-520/550:

1) We strongly suggest that routine cruise operations be conducted ONLY on the lean side of peak TIT.

2) Below 18,000', and while operating on the lean side of peak TIT, it is usually possible to obtain 27 to 30" Hg Manifold Pressure at 2500 RPM (or less). This is accomplished with the throttle in the WOT (Wide Open Throttle) position. Many pilots are mistakenly concerned that they will operate the engine at too high of a traditional "percentage" power setting, by cruise operations with the throttle in the WOT position. This concern is misplaced, for the reasons discussed below.

3) Every internal combustion engine operates more efficiently with the throttle wide open, than any other position. However, this does not mean that the engine will be operating at 100% power. On the contrary. Because of the precisely balanced cylinder to cylinder fuel/air ratios made possible by the ***turboGAMIjectors®*** fuel injectors installed in your engine, both the MIXTURE control and the propellor governor can be used to reduce or "modulate" the horsepower produced by the engine.

4) THEREFORE, we suggest that, in general, in cruise, that the engine be operated with the throttle in the WOT position, and the horsepower be controlled by appropriate use of the mixture and propellor governor controls as follows:

A) Set the propellor governor to produce an RPM of your choice, typically from 2300 to 2500 RPM. Lower may be used, but we find little reason to do so at cruise.

B) Set the mixture to a fuel flow that produces a TIT of from 50 to 100F lean of peak TIT.

1) Typically, on a (TN) IO-550 at WOT, this will be from 13.5 to 14.5 gph at 2300 RPM and from 14.5 to 15.8 gph at 2500 RPM.

2) Typically, on a (TN) IO-520 at WOT, this will be from 12.7 to 13.7 gph at 2300 RPM and from 13.7 to 15.0 gph at 2500 RPM.

NOTE: Do not think that you are "helping" the engine by using less than WOT and then select the fuel flows from the list above. This will simply result in the engine operating at much richer mixture with much higher CHTs.

3) The easiest way to select the right mixture is the following:

a) Leave the throttle at WOT coming out of the climb. Level off. Select the desired RPM. In this example, 2500 RPM.

b) Close the cowl flaps. Turn the boost pump OFF, if it was used during the climb.

c) Grasp the mixture knob and smoothly (use 3 to 5 seconds for this) reduce the mixture from the climb fuel flow to the middle or low end of the appropriate cruise fuel flow described above [paragraph 4.B) 1) & 2)].

d) Allow the engine to stabilize over the next 2 to 5 minutes, noting the TIT which should be below 1510F, and possibly as low as 1430F, depending upon the fuel flow selected and the particular engine installation. Monitor the CHTS. They should all be under 380F.

e) When you are comfortable, and the cockpit workload permits, slowly increase the mixture while watching the TIT. At some point, the TIT will reach a peak or maximum value, usually somewhere between 1540 and 1640F (note, again, the absolute peak TIT value varies significantly from one engine installation to another.) Note the maximum value of the TIT. Then, reverse the process, and lean the mixture until the mixture is set at a fuel flow that produces a TIT that is 50 to 100F lean of the peak TIT.

f) Observe the CHTs. If any CHT is above 380F, lean the mixture further so as to drop the

TIT by an additional 10 to 20F. Repeat as necessary in order to keep all cruise CHTs below 380F. Temporary CHTS in excess of 380F and below 410F are no cause of any concern. Temperatures above 410F should be dealt with promptly.

g) If the CHTs are all below 360, and you wish to operate at higher horsepower, feel free to increase the fuel flow in small increments and to thereby raise the TIT. In general, you should never have any occasion to operate the TIT closer than 30 to 40F from peak TIT on the lean side of peak TIT. In our experience, the engine performs best if the TIT is adjusted to values from 90 to 60 lean of peak.

NOTE: In the event you experience some occasional roughness from lean operations at high power in the area from 100 to 50 lean of peak TIT, the problem should be investigated. The usual causes are:

1) Bad spark plug;
2) Bad magneto or harness;
3) Leak in the induction system;
4) A partially plugged nozzle.

Operation at lean of peak mixtures requires an aggressively well maintained engine ignition system!

C) Calculating horsepower. A unique and highly useful feature of lean of peak operations (and ONLY lean of peak operations) is that you can readily calculate the horsepower of the (TN) IO-520/550 by the following formula, without regard to MP, RPM, Altitude, or OAT:

Horsepower = Fuel Flow (gph) multiplied by approximately 14.9 Hp/gal where the fuel temperature is measured at 60F.

Thus, if the engine is operated on the lean side of peak TIT, and the fuel flow is 14.5 gph, then the horsepower will be approximately 216 Hp, or on an IO-550 , approximately 72% of the maximum 300 rated continuous horsepower.

NOTE: The exact value of "14.9" is subject to some small debate. Depending upon the assumptions adopted, in making the necessary calculations to obtain that factor, its value will vary from about 14.85 up to about 15.1. As of April 3, 1999, we have adopted 14.9 as the reference number. This assumes that 100LL has a specific gravity of 0.695, which implies that 100LL weighs 5.79 lbs/gallon at 60F. This is an average of specific gravity data we obtained from a review of a number of refinery tests over several months.

D) Lower horsepower. If lower cruise horsepower is desired for any reason, consider achieving that result by First, reducing RPM; Second, by further leaning; and Third, by reducing the throttle.

E) A word about TIT values. In our experience, the absolute *indicated* value (as opposed to some theoretically perfectly calibrated TIT gage) of TITs at cruise settings varies as much as 50 to even 75F from one engine/airframe installation to another. We see this much variation, or more, for example, even on the same airplane, where there are two TIT probes installed. Typically, for the turbonormalized systems, the indicated maximum or peak cruise TITs tends to fall in one of two groups, that being either a group with peak TITs at high power that fall in the 1550 to 1600 range, or another group that tend to fall in the 1600 to 1650 range. We don't have a firm grasp on the resons for this difference yet, other than it is almost certainly an artifact of the installation and details of the probe placement and the wiring. However, while these rather large differences tend to show up on the high end of the scale, the variations on the low end of the scale, used for the "Target TIT" for takeoff and cruise climb tend to be much smaller, to the point that they are seldom more than 15 or 20 degrees different from one engine to another, under otherwise identical conditions.

Descents From Altitude For Approaches and Landing:

1) Many pilots are concerned about "shock cooling" their engines. There is a genuine debate as to whether or not this is a significant factor in engine longevity, but the methods described below will minimize rapid cylinder head temperature changes and provide very rapid descents from altitude.

3) Most pilots do not appreciate that the single most important factor in controlling engine cylinder head temperatures is the control of engine exhaust gas temperatures (TIT). Thus, the almost universally overlooked key factor in making rapid descents from altitude is the necessity to properly manage the TIT during the descent.

4) With this consideration in mind, we suggest that descents from altitude be made as follows:

A) SMOOTHLY (over a period of 3 to 5 seconds) reduce MP from WOT to approximately 15 to 18" MP.

B) SMOOTHLY reduce RPM to a value in the low end of the green arc on the tachometer gage. Use as low an RPM as can be achieved, given the limitations of airspeed and the coarse pitch stops of the particular propellor. This may be anywhere from 1800 to 2300 RPM, depending upon the particular propellor, the altitude, and airspeed.

C) RESET THE MIXTURE CONTROL SO AS TO OPERATE THE TIT AT ITS MAXIMUM POSSIBLE VALUE. This will typically result in TIT values from 1300F to 1400F at 15 to 18" MP and the reduced RPM, with a fuel flow from (typically) 7 to 9.5 gph. This step is ABSOLUTELY CRUCIAL. The point is to operate the mixture so as to produce the hottest possible exhaust gas temperature during the descent. The hot exhaust gases will keep the CHTs warm during the descent. (Note: this exercise may require you to either enrichen the mixture slightly or to lean the mixture slightly from its previous cruise mixture setting. Regardless, you must simply move the mixture one direction, and note if the TIT is going UP or DOWN. If it is going DOWN, then reverse the process and move the mixture in the opposite direction until you force the TIT to a value near or just slightly (10 to 20F) rich of its maximum or peak value at those low power settings.

D) Descend at an airspeed appropriate for the turbulence or other conditions.

Landings:

1) Landings are performed in the conventional manner.

2) Because the mixture is set to allow for increased fuel flows during climbs to high altitudes, you may wish to establish a practice of setting the mixture at some intermediate position that is not full rich during the approach and landing. (See the topic: "Instrument Approaches", below.) This should, however, be done with caution, and you should determine that mixture setting that will afford adequate fuel for an immediate full power go around, during which the TIT will not exceed approximately 1350 F.

3) In this connection, the pilot of a piston aircraft that demands the use of the mixture control as an integral part of the proper overall management of the engine must teach himself or herself good habit patterns with respect to the application of large changes in power.

A) When making a large increase in power, always begin with an increase in the mixture, then an increase in the RPM and then an increase in manifold pressure. You should practice this drill until it becomes second nature.

4) After landing, and after clearing the active runway, and coming to a complete stop, carefully identify the flap lever and raise the flaps. Identify the cowl flap lever and open the cowl flaps. Then aggressively lean the mixture, as described above, under "Startup, Taxi, and Runup."

5) Turbo cool down. Many pilots believe it necessary to allow a period of two to five minutes after landing for the turbocharger to cool down. In our experience, unless the approach to the landing has been made under high power, (ie, a long "drag in" type approach) this is seldom necessary. Usually the approach to the landing is made at low power and the turbo has an adequate opportunity to cool off before shutdown.

ONE IMPORTANT THING TO REMEMBER:

Many pilots ask:

"Where should I set my mixture?"
This question is very difficult to answer in less than a book. A much easier question to answer is:

"Where should I NOT set the mixture?"

At high power settings, do not set the mixture so as to operate any of the six cylinders on a (TN) IO-520/550 engine between 25F on the lean side of peak TIT and 150F on the rich side of peak TIT.

At any other power setting, other than a high power setting, it really doesn't make a lot of difference where you set the mixture, as long as you are aware that excessively rich mixtures cause fouled spark plugs, stuck rings, stuck/bent exhaust valves, and other bad things in your engine.

INSTRUMENT APPROACHES:

In general, instrument approaches will be made in the same manner as you have always conducted such approaches.

Pilots who have developed specific power settings to be used during different phases of the instrument approach will need to slightly adjust those MP and mixture settings when moving to the turbonormalized aircraft, or any turbocharged aircraft, for that matter.

Some considerations are:

1) At low altitudes where most instrument approaches take place, the turbocharger turbine and compressor react to the throttle somewhat differently than does a normally aspirated engine. These differences are neither good, nor bad, just "different", and are fairly typical of all turbocharged aircraft engines.

2) Because of the design of the absolute pressure controller, the exhaust system experiences modest amounts of back pressure (when compared to manifold pressure) when the pilot selects lower intermediate manifold pressure settings during the approach. This effect largely disappears at high power settings, but it is significant at lower MP settings. Thus, if a pilot of a normally aspirated aircraft customarily used, for example, 19" MP for some phase of the instrument approach ("Outer Marker - outbound", as an example) , the pilot will probably find that 21 or 22" MP is required to accomplish the same manuever with a turbocharged or turbonormalized version of the same aircraft.

3) Mixture control is also a significant issue. As described elsewhere, the full power mixture on these aircraft is deliberately set up rather rich in connection with specific high altitude certification requirements. In our experience, the aircraft throttle responds in the most traditional manner at partial throttle settings at low altitudes during the approach if the mixture control is positioned sometime, early in the approach, so as to provide a TIT value of between 1350 F to 1450 F at a MP and RPM setting of approximately 23" MP and 2500 RPM. This mixture control setting can then remain constant as the throttle is manipulated to accomplish the various approach maneuvers, subject to the caution, below, concerning the proper use of the mixture and prop controls during a missed approach or balked landing.

4) Each pilot making the transition to turbocharged or turbonormalized aircraft of any description should specifically train themselves in, and pay attention to, the proper sequence for the use of the mixture, prop and throttles during critical portions of flight when there are large increases in power, such as a missed approach. This requires conscious practice to establish a habit of first increasing the mixture, then the propellor control, and then the throttle, during the missed approach or balked landing exercise. We suggest that, as an aid in this training, that the pilot, on every takeoff, always start the application of takeoff power by touching the mixture control to make sure it is properly advanced, then the prop control, and THEN, last, the throttle.

THE MOST IMPORTANT THING TO REMEMBER:

The most important factors in a safe flight are a well informed, well trained and currently experienced pilot, in good health, well rested, flying a well maintained aircraft, in appropriate weather.

Other Issues:

The suggestions stated above have been developed based upon operational experience. In some instances, those suggestions are significantly different than customary operating practices that are widespread in general aviation flying. TCM has, for example, expressly stated in open public meetings, that operating their engines "lean of peak" will not hurt the engines. However, each pilot should be aware of possible warranty issues, and should operate the engine so as to comply with all applicable warranties.

Operation of the TN(IO-550) on the lean side of peak TIT at WOT at fuel flows in excess of 15.5 gph might, for example, produce more than the TCM recommended 78% (234 Hp) maximum continuous power for that engine. However, when operated as suggested in this document, the measured cylinder head temperatures and the measured internal peak cylinder pressures remain substantially lower, than the same engine operated at the same horsepower, but 100 F rich of peak TIT.

Operation of the (TN)IO-520 has a similar consideration, except that the factory recommended maximum continuous cruise power setting is 75%. This means that operation of this engine on the lean side of peak TIT at WOT at fuel flows in excess of 14.0 gph may produce more than the book stated 75% (214 Hp). Again, the measured cylinder head temperatures and the measured internal peak cylinder pressures remain substantially lower than the same engine operated at the same horsepower, but 100 F rich of peak TIT.

These are issues that each pilot must resolve and decide for himself or herself.

Ultimate Engines in Mena, Arkansas, has investigated this matter, and looked at the relevant data. That well regarded engine shop will build/re-build an IO-520 or IO-550 for installation as a (TN)IO-520/550 and will afford their standard warranty if the engine is operated as described in this document, even at horsepower settings up to 83% of maximum rated power.

Your Suggestions are Welcome! If you have any suggestions as to how this document might be improved, please forward such suggestions to Tornado Alley Turbo, Inc., Ada Municipal Airport, Ada, Oklahoma, 74820.

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