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

Equipped with the Tornado Alley Turbo, Inc., "Whirlwind System III"

Rev. (27 October, 2014)

Note: This revision is specifically directed at those systems that have been upgraded to the "Whirlwind System III" configuration. This separate version of these "Suggestions" is necessary because the substantial performance improvements obtained with the "Whirlwind System III" and alter some of the recommendations contained in earlier versions of these suggested operating considerations. These suggestions do not pertain to the systems prior to the "Whirlwind III".

Startup, Taxi, and Run-up

Startup, taxi, and run-up are normal, except for the following considerations:

Consider aggressive leaning, lean to maximum RPM 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.

If the mixture is leaned past peak RPM at idle for the magneto check, you will see a larger than normal drop in RPM. Slightly enrich the mixture and try the magneto check again. Any significant difference between the LEFT/RIGHT magnetos or a drop in EGT on any cylinder 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 loss of power and higher than normal EGTs and TIT. Conversely, any advance in the timing over the spec 22 degree value, may cause excessive internal cylinder pressures and other problems associated with that condition, including, specifically, higher than normally anticipated cylinder head temperatures.

Takeoff

1. Follow the POH supplement in this regard. Consider the following: Normally, at full rich, the TIT will be between 1250°F and 1320°F on the TIT, during a full power takeoff.

2. On normal days and runways, the new "Whirlwind system III" should always use the full rich mixture setting for normal takeoffs.

3. All new "Whirlwind System II" installations are equipped with the two speed fuel boost pump (LOW /OFF/ HIGH). For those older IO-520 systems that do not have the two speed pump, we strongly encourage a retrofit. DO NOT USE the HIGH/ON position during takeoff unless there is a failure of the engine driven fuel pump. Making this mistake will cause the engine to become so rich as to possibly “stumble” or even quit altogether, and in any event, the engine will make substantially less than full rated power when the boost pump is misused in this manner. 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 at normal operating temperatures, the MP may momentarily exceed the red line 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 redline by more than approximately 2", you should promptly reduce the throttle so that the MP is at the red line. The engine is afforded some protection by a mechanical "pop-off" valve in the event of a serious over pressure from the turbocharger and/or the automatic waste gate controller.

Climbs

1. In general, use full throttle and 2700 RPM during the climb. There is really no reason to use a reduced RPM, such as 2500 RPM, during the climb. Our research suggests that the engine is probably better off operating at 2700 during the climb, than 2500 RPM. Unless the engine is over-boosting for some reason, DO NOT USE PARTIAL THROTTLE POSITIONS DURING THE CLIMB.

Partial throttle does not help the engine, it prolongs the climb, and it may actually result in higher CHTs during the climb, when compared to the routine use of Wide Open Throttle (WOT).

2. Cowl Flaps FULL OPEN.

3. During the climb the hottest CHT should be monitored. The mixture will be full rich unless once the boost pump is activated the fuel flow is too high which occurs primarily in the B36 conversions. The hottest CHT is monitored and kept below 380°F by activating the low boost pump at 5000′ Density Altitude and high boost at 10000′ Density Altitude and also by keeping the indicated climb speed usually 115-120 KIAS. In some cases during when the OAT is +15-20 above standard ISA temperatures you may need to accelerate as high as 130 KIAS. Add the speed in 5 knot increments and wait a few minutes to see if it has an effect. 5 knots in indicated airspeed will make a big difference in cooling air through the engine compartment.

   NOTE: Sometimes vapor will form in the fuel system during a climb. This happens even with normally aspirated IO-550/520 engines, on a routine basis during hot weather. Warm day, fuel, and high rates of climb to altitude exacerbate this tendency. 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. 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.

After the climb is complete, you should return the boost pump to the OFF or LOW position, and re-lean the mixture for cruise as described elsewhere.

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, or even cause the engine to quit. 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 18,000-22,000' (depending on the condition of the turbo, the engine, and the plumbing), and while operating on the lean side of peak TIT, you should routinely be able to obtain 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 ***turboGAMIjector®*** fuel injectors installed in your engine, both the MIXTURE control and the propeller 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 propeller governor controls as follows:

    1. Initially, set the propeller governor to produce 2500 RPM.

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

        1. "Whirlwind System II"
           Typically, on a (TN) IO-550 at WOT, this will be from 15.5 to 17.0 GPH.
           Typically, on a (TN) IO-520 at WOT, this will be from 14.5 to 16.0 GPH.

        2. "Whilwind System II with Rammer II"
           Typically, on a (TN) IO-550 at WOT, this will be from 16.0 to 17.5 GPH.
           Typically, on a (TN) IO-520 at WOT, this will be from 15.0 to 16.5 GPH.

        3. "Whilwind System III with Rammer II and scoop"
           Typically, on a (TN) IO-550 at WOT, this will be from 16.5 to 18.0 GPH.

Typically, on a (TN) IO-520 at WOT, this will be from 15.5 to 17.0 GPH.

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 CHT's.

4. The easiest way to select the right mixture is the following:

    1. Leave the power settings at WOT - Full Rich-2700 RPM coming out of the climb. Level off. Allow the aircraft to accelerate.

    2. As the aircraft accelerates, close the cowl flaps. Turn the boost pump OFF if it was used during the climb, but if the fuel flow is not steady, then use LO boost for the next half hour until the fuel in the tanks cools off to ambient.

    3. Set the RPM to 2500. Not 2300 or anything else, just start at 2500 RPM.

    4. 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), & 3)].

5. Allow the engine to stabilize over the next 2 to 5 minutes, noting the TIT which is usually between 1500-1600°F, depending upon the fuel flow selected and the particular engine installation. Monitor the CHT's. They should all be under 380°F. If they are above 380°F and not declining, then lean the mixture 0.2-0.3 GPH and continue monitoring the CHT's. If the OAT temperature is +15-20 above standard ISA day for that altitude you may need to operate with the cowl flaps approximately half open. This completes the leaning requirements.

6. If you want LOWER horsepower (for extended range, for example) than you have set with WOT and 2500 RPM, accomplish this as follows:

   Simply reduce the RPM from 2500 to 2400, or 2300. Do not go lower than 2300 RPM with manifold pressure above 25" Hg. Do not change the throttle. Generally, you do not have to readjust the mixture setting as the fuel flow will fall in proportion to the reduction in RPM and the resulting lean of peak fuel/air ratio remains constant at the previously set LOP fuel setting. Later, if you want more horsepower, simply increase the RPM back to 2500, without adjusting the mixture or throttle.

   If you need still further horsepower reduction, then, consider simply reducing the throttle. If you are operating at 25-30" Hg MAP, then you may need to lean some. By reducing the throttle only you have enriched the mixture. At these power settings the engine may be too close to peak and the CHT's may begin to become too hot.

7. When you are comfortable, and the cockpit workload permits, and you just have to know how far lean of peak you are, you can do the following: Open the cowl flaps. Note the current value of the TIT. Then, slowly increase the mixture while watching the digital values of the TIT. At some point, the TIT will reach a peak or maximum value, usually somewhere between 1540 and 1680°F (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, leaning the mixture until the mixture is set at a fuel flow that produces a TIT that is 50 to 100°F lean of the peak TIT.

8. Observe the CHT's. If any CHT is above 380°F, lean the mixture 0.2-0.3 GPH and monitor the CHT's to verify they have dropped below 380°F. Temporary CHT's in excess of 380°F and below 410°F are no cause of any concern but for continuous operation we recommend keeping the hottest CHT below 380°F. Temperatures above 410°F should be dealt with promptly. The engines maximum CHT of 460°F has not been changed but we have found that excessive cylinder wear occurs above CHT's of

415°F.

NOTE: In the event you experience some occasional roughness from lean operations at high power in the area from 50 to 100°F 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!

3. 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 MAP, RPM, Altitude, or OAT:

   Horsepower = Fuel Flow (GPH) multiplied by approximately 14.9 Hp/gal.

   Thus, if the engine is operated on the lean side of peak TIT, and the fuel flow is 15.8 GPH, then the horsepower will be approximately 235 Hp, or on an IO-550 , approximately 78% of the maximum 300 rated continuous horsepower.

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.

2. Most pilots do not appreciate that the single most important factor in controlling engine cylinder head temperatures is the understanding and 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.

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

    1. SMOOTHLY (over a period of 3 to 5 seconds) reduce MAP from WOT to approximately 15 to 18" Hg MAP.

    2. 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 propeller. This may be anywhere from 1800 to 2300 RPM, depending upon the particular propeller, the altitude, and airspeed.

    3. Typically, this is all you have to do. When you do steps A) and B), the resulting TIT, on the properly set up (TN) IO-550/520 will end up at or very near peak TIT, somewhere around 1300 to 1400°F with 15 to 18" Hg MAP and the reduced RPM, with fuel flows from 7 to 9.5 GPH. This is precisely where you

want the TIT to be during a low power descent. However, to satisfy yourself that the TIT is at approximately peak TIT, after making the power reductions described in A) and B), you can RESET THE MIXTURE CONTROL SO AS TO OPERATE THE TIT AT ITS MAXIMUM POSSIBLE VALUE. The point is to operate the mixture so as to produce the hottest possible exhaust gas temperature during the descent. This can be difficult since the TIT is changing due to the lowered power setting and the MAP is increasing as you descend. This adjustment in mixture is not necessary since the fuel controller on the aircraft modulates the fuel flow so that when the throttle is reduced the mixture gets richer. (If a normal descent power setting of 23" Hg MAP and 2300 RPM is used you are very close to peak TIT. Using the lower power setting of 15" Hg MAP and 1800 RPM will increase the rate of descent, but the change in mixture at that low of a power setting will not make a significant difference in the engine CHT's. In the lower altitudes the RPM reduction does not significantly increase the descent rate; in fact below approximately 8000' MSL 2300 RPM will give you a higher descent rate.) The hot exhaust gases will help keep the CHT's warm during the descent. (Note: this exercise may require you to either enrich 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 20°F) rich of its maximum or peak value at those low power settings.

4. Descend at an indicated 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 need to only enrich 1-2 GPH during the approach and landing. (See the topic: "Instrument Approaches", below.) This should, however, be done with caution, any full power go around would need to be preceded by moving the mixture control to the full rich position.

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.

    1. 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. Reset the trim for the next takeoff. Then aggressively lean the mixture (if

the mixture was enriched more than the 1-2 GPH, if not your mixture is already set for taxi), as described above, under "Startup, Taxi, and Run-up."

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. From data we have seen and consistent with our experience, unless the approach to the landing has been made under high power, (i.e. 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 during a typical taxi to the ramp. During the taxi phase, if it is necessary to use a lot of power for a turn into a parking area, or for some similar reason, then wait for 10 to 15 seconds after you power down to allow the turbo RPM to return to its normal idle speed, before shutting the engine down

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 (above 65%), do not set the mixture so as to operate the (TN) IO-520/550 engine between 50°F on the lean side of peak TIT and 125°F on the rich side of peak TIT.

At any other power setting (65% or below), 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 MAP 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 MAP settings. Thus, if a pilot of a

normally aspirated aircraft customarily used, for example, 19" Hg MAP for some phase of the instrument approach ("Outer Marker - outbound", as an example) , the pilot will probably find that 21 or 22" Hg MAP is required to accomplish the same maneuver 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, to add 1-2 GPH. 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 PROPELLER 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, and 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 him or herself.

Various engine shops have looked at the relevant data on this issue. These well regarded engine shops will build/rebuild 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.

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., 300 Airport Rd., Ada, Oklahoma, 74820.

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