Turbonormalizing Vs Turbocharging.

Understanding the important differences

Let us begin.

TN and TC engines share the following characteristics:

A. Both involve compressing outside ambient air to make it available as denser air to the engine induction system so that the engine can make more power.
B. The degree to which the air is compressed is just a matter of design choice when one decides to specify the engine and its ability to make horsepower across the normal range of desired altitudes.
C. Any time you compress air - you make it hotter. (As discussed below - almost everybody in the early days missed the importance of intercoolers.)
D. Both TN and TC systems use an exhaust driven turbine to drive a centrifugal compressor - at speeds that may range as high as 120,000 RPM on some units.
E. Both TN and TC systems can use the same turbo components.

The TN system designer typically starts with a normally aspirated engine and asks the following question:

What is the minimal number of changes one can make to this existing NA engine and still have that engine make sea level power at altitude (typically > 18,000 feet)?

The answer includes a laundry list like this:

1. New exhaust system to get the exhaust to the turbo housing.
2. Add turbo charger or two of them.
3. Add some way to control the speed of the turbo charger - ie, a wastegate.
4. Manual or automatic control over the wastegate?
5. Intercooler ? Very desirable, but not absolutely mandatory.
6. Fuel injectors that have the air side referenced to the output of the turbocharger compressor.
7. Fuel pump and fuel metering changes that will let the engine work gracefully with the higher pressure air over a broader range of operating conditions.
8. Need to enhance the cooling of the overall system (both cylinder head and possibly oil cooling), since it will be flying in thinner air at altitude that inherently provides less cooling.
9. Mechanically support the weight of the turbochargers.
The reality is that **the TC system designer** actually started with the same question. Keep in mind that almost all of the fundamental design decisions for the TCM TSIO series of engines and the Lycoming TIO series of engines were made back in the 1963 to 1968 time frame.

In 1963, at TCM, the question was something like this: "What can we do to modify the existing 260 Hp IO-470, or the new 285 Hp IO-520 normally aspirated engines - to make a turbocharged engine to sell to Cessna?" [History note: *The first C-320 aircraft* (in 1964) were equipped with TSIO-470 engines. A couple of years later, they switched to TSIO-520 engines with 285Hp, just like the Cessna 310s were also switched to IO-520 normally aspirated engines.]

[Another history note: *Remember, Jack Riley was running amok back then putting Lycoming normally aspirated IO-540s on C-310’s with turbochargers and operating them as "turbo normalized" engines and calling them Riley Rockets! TCM just HAD to come up with a turbocharged engine or they ran the risk that Cessna might go to Lycoming for engines for the C-310. The term "turbonormalized" was not used, until later.*]

And guess what? TCM ended up developing exactly the same basic list of 9 items (see above) as for the TN engine - but with one additional item.

[Some more history: *The then universe of general aviation piston engine engineers mostly had a background in the big supercharged radial engines - all of which had very low compression ratios (often down around 6.5:1). All of those engineers just assumed that they would have to reduce the compression ratio on their new turbo-supercharged flat six cylinder engines in line with their previous big radial engine experience.*]

So that is exactly what they did. TCM reduced the CR from 8.5:1 down to 7.5:1. Lycoming typically went from around 8.7:1 down to 7.3:1. There were some variations.

So, now, take the list of nine items above, and add item number 10.

10. Change the piston geometry to reduce the compression ratio by about 1 point, from ~ 8.5 down to 7.5:1.

When you do that you have identified the only meaningful "difference" in the hardware between our common terminology of turbonormalizing and turbocharging.

Yes, it is true that the typical turbonormalizer on a 285 Hp IO-520 TCM engine only uses around 30" of MP and the typical early Turbocharged engine (TSIO-520D in the 1968 Cessna 320F, for example) uses around 32.5" Hg to make the SAME 285 Hp at sea level.

However, bear in mind, the extra 2.5" of manifold pressure (from 30” up to 32.5” Hg) is there to make up for two things: First, some minor losses in the exhaust system back pressure and second, and more important, to make up for the fact that the air was HOTTER in the non-intercooled induction system in the Cessna 320 and was therefore "LESS DENSE" and it took higher MP to get the same total mass air flow through the engine - in order to make the same 285 Hp - and to make up for the loss in overall efficiency because of the lower compression ratio.
Important note: None of those early turbocharged or turbonormalized engines had intercoolers! Not the Cessna T-210. Not the Cessna 320. Not the Cessna 310T. Not the Bonanza V35TC. Not the Bonanza A36TC nor the Bonanza B36TC. None of them. There were, in the early days, a number of RAY-JAY "turbo normalized" after market STCs that were added to several Mooneys and to some Bonanzas. None of them worked well. Most were really bad. That caused some early heart burn with the OEM’s who condemned those early non-intercooled non-OEM 8.5:1 compression ratio installations - and often for good reason. Had those early aftermarket STC’d installations with the 8.5:1 compression ratios been equipped with good intercoolers and good cylinder and oil cooling, the valid engineering reasons to object to them would have been eliminated, although, undoubtedly, Lycoming and TCM would have still found an excuse to complain, just for marketing reasons.

[Another history note: For a while, the Piper factory did do installations of what we now call turbonormalized engines using the RAY-JAY hardware. There were no intercoolers. This was done on some Comanche and Twin Comanche aircraft and some Apache aircraft with Lycoming IO-540 engines. Then Lycoming changed to low compression pistons and provided an OEM engine to Piper as a TIO-540x series engine. Again, there were no intercoolers. Forty years later, the earlier, higher compression configuration engines are, today, much preferred by knowledgeable pilot-owners, as opposed to the later models with the typical 7.3:1 compression ratio engine configurations.]

If, in the years around the 1963 time frame, TCM (and, later, Lycoming) engineers had readily available cost effective air-to-air heat exchangers (intercoolers) and had the airframe OEM companies then been willing to go to the trouble and expense to integrate the somewhat more complex design required to employ the intercoolers effectively, it is likely that some engineer would have realized that it would be “a good thing” if the early turbocharged engines used in the Cessna T-210 and Cessna 320 and the Piper Comanche would have kept their original 8.5 (8.7):1 compression ratio engines. Thus, the several problems (mostly heat and temperature and fuel consumption) associated with 7.5:1 compression ratio engines would have largely been avoided.

But the OEMs were in a hurry for a quick fix - or a "drop in" turbo engine that would be a “one design” that would fit in a broad cross section of existing Cessna and Piper air frames without extensive airframe modifications. That was a lot easier to do by changing the piston to get a 7.5:1 compression ratio than it was to keep the 8.5:1 compression ratio and figure out a way to stuff a good intercooler into the multiple different cowlings that existed among dozens of different airframes.

A current technology "good" intercooler design can reduce the induction air temperature so that turbocharged or turbonormalized engines see induction air temperatures that are much more comparable at all altitudes and power settings to a hot day normally aspirated engine than they are to a non-intercooled turbocharged engine. But nobody back in the 1963-1970 timeframe was properly focused on the importance of the intercooler to optimize and make truly successful the highly desirable change from normally aspirated engines to turbocharged engines.

Worse, because of the routine absence of the intercoolers in the design of the early turbocharged (and early turbo-normalized) engines in the 1960s, the owners ended
up having a series of unsatisfactory engine life operational experiences. Those less than good experiences became widely circulated as the prevailing "wisdom" of the time. Those old perceived "truths" are very hard to correct in the often tradition bound aviation community.

Last, the pilots and mechanics should really be aware that there is nothing "magic" about 29.9" Hg manifold pressure verses 32.5" Hg manifold pressure or even 36 or 38" Hg manifold pressure. One is not necessarily "harder" on the engine than is the other. The engineering parameters that "make a difference" are evident in other data that the pilot never sees. The important constraints on good engine durability is only evident in the data from the individual combustion events and that is primarily the magnitude of the maximum instantaneous internal cylinder pressure and its occurrence with respect to top dead center of piston travel, along with the magnitude of the operating cylinder head temperature.

If a design engineer properly manages the instantaneous peak internal cylinder pressure (which is a VERY different parameter from the more widely known BMEP) and the cylinder head temperatures, then the magnitude of the manifold pressure becomes very much less important in a discussion of engine durability.

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