The Effects of Charge Air Cooling on Turbocharged Engines

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Most pilots subscribe to the adage, "fuel is cheaper than engines". Certainly, using more fuel to cool the engine is cheaper than burning a piston or a valve due to a hot lean mixture. Of course, lean mixtures can lead to detonation which exists when the super-hot compressed fuel/air mixture prematurely explodes, instead of burning with a smooth flame front across the piston dome. Adding more fuel to the mixture can discourage the tendency to detonate.

Another, more effective, method to prevent detonation is to provide cool compressed air to the mixture. Cool compressed air provides the same effect on detonation protection as a rich fuel mixture, and provides an extra margin of engine operational safety. The graph in Figure (#1) shows the thermodynamic effects of intercooling, or reduction in charge air temperature, on an aircraft engine's detonation limits. The graph is presented to illustrate our discussion of engine detonation limits. It is typical of modern aircraft engines and the trends shown are substantiated by independent technical information previously published by the Society of Automotive Engineers. Shown on the left side or vertical axis of the graph is the maximum I.M.E.P. or the Indicated Mean Effective Pressure inside the cylinder that can be maintained before a potential for engine detonation occurs. At the bottom or horizontal axis of the graph is charge air temperature, or temperature of the compressed air entering the engine.

The chart points out how cooling the charge air offers similar detonation protection as running a richer mixture. For example, assuming a 180 PSI cylinder pressure with 250°F charge air temperature at best power mixture (point C), (100°F rich of peak EGT); reducing the charge air temperature to 130°F (point D), allows the same 180 PSI pressure to be maintained while the engine is leaned to best economy fuel flow (or peak EGT). Cool charge air can allow an engine to be operated at best economy fuel flows, with equal or better detonation margins as when operating with hot charge air,

richer mixtures and much higher fuel consumption.

Referring to the chart, one can also see that at best economy mixture, (peak EGT setting), a charge air temperature of 200°F (point A) will allow only an I.M.E.P (cylinder pressure) of 150 PSI without detonation. By simply cooling the charge air temperature to 100°F, and keeping all other parameters constant, (pointB) the maximum allowable I.M.E.P. increased to 210 PSI, a 40% improvement in allowable pressure for the same fuel mixture.

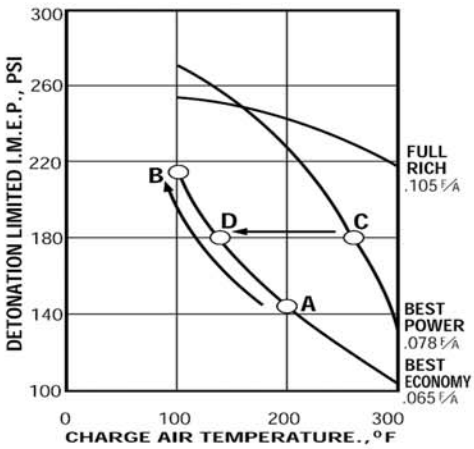

Figure 1.– Effect of charge air temperature on detonation-limited cylinder output. Compression ratio, engine speed, spark advance, and cylinder temperature held constant. (Droegemueller, Hersey, and Kuhrt, J. SAE).

So what does all of this have to do with the Cessna 340 and 414 aircraft where our interests lie. Well, specifically American Aviation supplies an efficient intercooling system "Ultracooling™" that reduces induction air in the 340 and 414 aircraft approximately 100°F at cruise altitudes and power settings. (Coincidentally, the same number as in our example Figure 1.)

With Ultracooling, the pilot can run leaner mixtures and still obtain equal to or better detonation margins. At say 65% power settings, if the pilot normally runs 100 to 125°F or more rich of peak EGT, he can now lean the mixtures closer to peak EGT, still on the rich side, and save fuel. Now back to the old adage, "fuel is cheaper than engines." With Ultracooled engines, even conservative leaning can result in 2 gph per side savings or 4 gph total. At $5.00 per gallon this is a $20.00 per hour savings and over a 1600 hr. TBO of the engine, this results in a $32,000.00 savings in fuel. The point here is that fuel isn't exactly cheap either. If you can reduce fuel consumption and maintain good detonation margins with a quality intercooling system it's certainly worth considering.

Recently, Mr. Peter Garrison of Flying Magazine investigated our Ultracooling system for the 340 and 414 aircraft and he had similar views, for example he said, "Fuel is expensive, but turbochargers and cylinders are too; I feel that the best way to go easy on an engine is to operate at moderate power settings - as judged by fuel flows reported by an electronic transducer, not mp/rpm combinations-with a lean mixture and moderate CHTs. Intercooling makes it easier to do this, and so my inclination is to regard any well designed intercooling system as a benefit."

Regarding the effects of hot and cold induction air and engine life, he said, "To the extent that you can harm your engine, you're much more likely to do it with heat than with cold ". He further explains that "with efficient intercooling, you can use mixture settings closer to peak or even at peak and get much lower fuel flows, so long as turbocharger inlet temperatures stay below limits (normally 1650°F) and cylinder head temperatures are below 400°F." American Aviation publishes specific recommended power setting charts for all models of 340 and 414 Cessnas equipped with Ultracoolers including all aircraft with Ram modified engines.

We believe that operating your engines according to this information will extend engine life, save fuel, and increase your overall satisfaction with your Twin Cessna.

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