The Effects of Charge Air Cooling in the TIO-540-J2BD Engine

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Most pilots subscribe to the adage, "Fuel is cheaper than engines." An interpretation of that statement might be "using more fuel to cool the engine is cheaper than burning the engine up before TBO." All other conditions remaining the same, this concept is, essentially, correct. The idea is to keep the compressed fuel/air mixture rich enough to keep from detonating. Detonation is the heat producing, piston eating, cylinder scoring, valve burning condition which exists when the super-hot compressed fuel/air mixture prematurely explodes, instead of igniting cleanly as it should. Adding more fuel to the mixture can discourage the tendency to detonate.

Another, more effective, method to tame the fire 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 the 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 the same 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, (point B) the maximum allowable I.M.E.P. goes to 210 PSI, a 40% improvement in allowable pressure for the same fuel mixture.

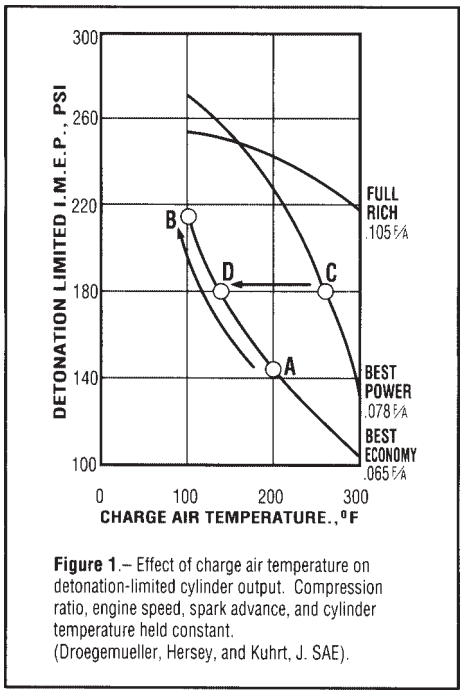

Figure 1.– Effect of charge air temperature on detonation-limited cylinder output. Compression ratio, engine speed, spark advance, and cylinder temperature held constant.
(Droegemueller, Hersey, and Kuhrt, J. SAE).

Cool charge air is the direct result of intercooling. Intercooling the TIO 540 engine will allow the operator to run leaner mixtures and still obtain equal to or greater detonation margins. If the operator 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 intercooled TIO 540's, conservative leaning can result in 3 gph per side savings or 6 gph total. At $5.00 per gallon this is a $30.00 per hour savings and over the 1600 hr. TBO of the engine, this results in a $48,000.00 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. In addition, safer single engine performance, better climb and faster cruising speeds are all options once the airplane is intercooled.

More than 30% of the existing Navajos are already equipped with the intercooling system and operators report more performance and smoother running engines.

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