QUANTITATIVE EVALUATION OF PIPER PAWNEE TOW PLANE LETDOWN

by Scott McMaster

This is the second article dealing with our investigation of tow plane letdown procedures. In the first, we detailed our investigation of premature cylinder cracking in SOSA's modified 180hp Citabria using a data collection device called the Flight Monitoring System (FMS). Once the Citabria's problem was solved it seemed only prudent to use the FMS system to check our Pawnee, even though we have had no trouble with it to date. The Pawnee is C-GGDK, a Pa-25/235. It has had the chemical hoper, spray booms, and wire cutters removed and a tow hook, rear view mirrors, and 4-bladed propeller installed.

Piper Pawnee C-GGDK of the SOSA Gliding Club, Rockton, Ontario, photographed during the IAS calibration formation flights with the club's Citabria, C-GKXJ. Pilot Scott McMaster.

For those who missed the first article, a quick recap of the FMS and our test procedures is in order. The FMS is a microprocessor based, real time data acquisition system designed and built by the authors. Its task is similar to that of the "black boxes" that are used in airliners: to record flight data for later analysis. For the Pawnee we used the FMS to record three cylinder head temperatures (CHTs), indicated airspeed (IAS), altitude, and engine RPM. One complete set of readings was taken every 2 seconds. The CHT probes used type K (chromel-alumel) thermocouples mounted in the holes provided by the manufacturer for CHT measurements. Although the rear cylinder is generally the primary concern in cooling problems, we instrumented the number 1, 3, and 5 cylinders (front, middle, and back, respectively, on the right side) to ensure no secondary cooling effects were missed. The dynamic and static pressures were taken from a test pitot head assembly mounted on the outer starboard jury strut. The probes extended 12" ahead of the forward strut in order to clear airflow disturbances caused by the wing. The pressures from the pitot head were measured using a differential and an absolute pressure transducer located in the FMS. Conversion of pressure to IAS and altitude above ground level (AGL) were done offline with software, as were altimeter setting changes. RPM was measured with a photocell mounted behind the propeller. The photocell produced a signal each time light was blocked by a propeller blade passing in front of it allowing RPM to be determined using a simple timing and counting circuit.

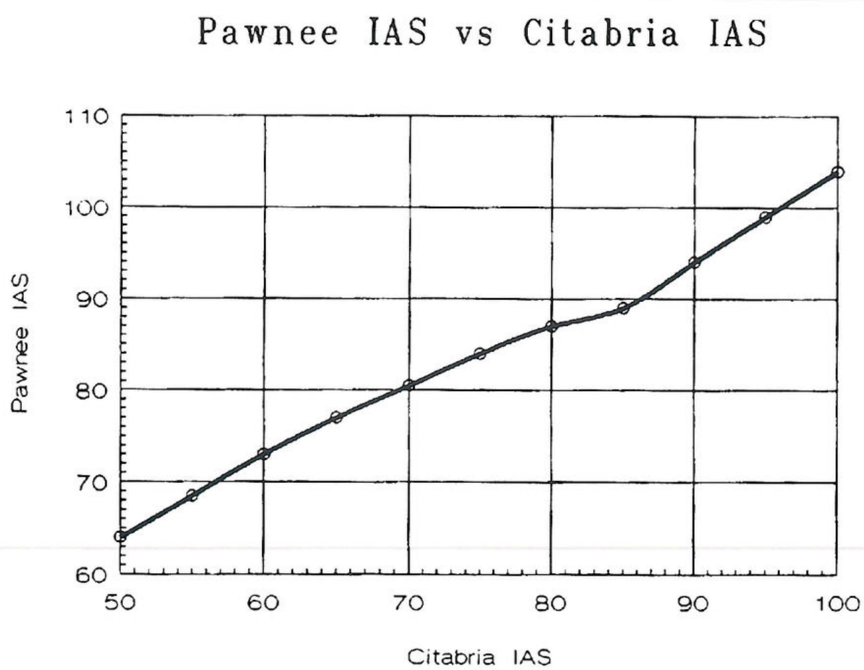

Figure 1. Calibration of our Pawnee's IAS to our Citabria's IAS. Calibration was obtained by comparing instrument readings during formation flight.

The actual test procedures were the

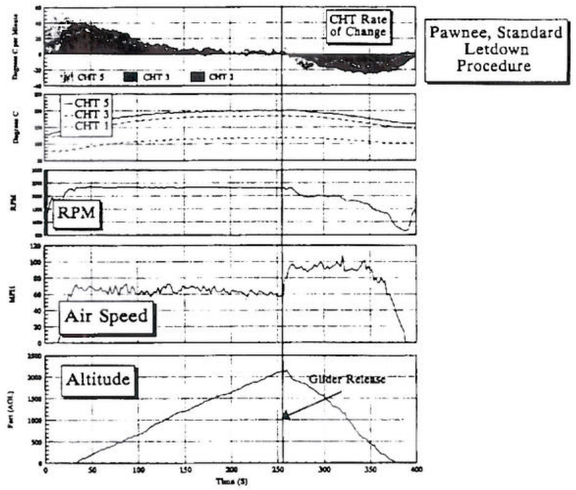

Figure 2. Flight profile during a nominal letdown. Note that the greatest cooling rate occurs as the throttle is reduced in the circuit, but never exceeds 28 °C per minute.

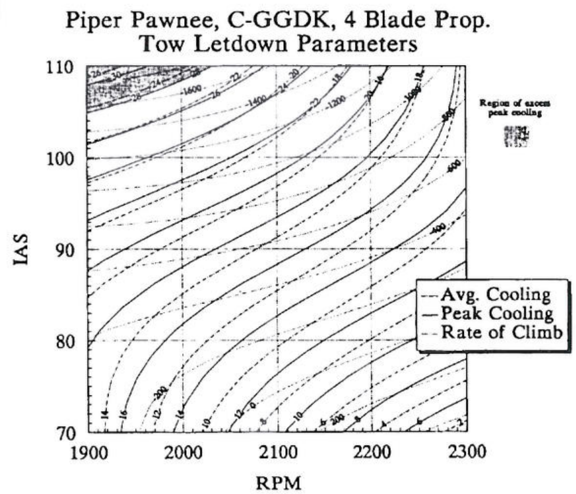

Figure 3. Pawnee letdown parameters. Cooling rates shown are those obtained in the first minute after glider release if the RPM and IAS are rapidly established. The rates are slightly lower if RPM and IAS are established more slowly. The rate of descent is about 200 fpm greater than that achieved using a 2-bladed propeller.

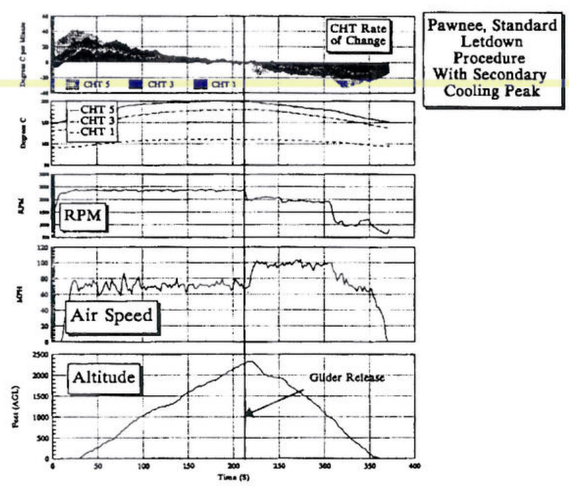

Figure 4. The Pawnee retains engine heat so well that excess cooling can occur well after glider release. Here power is kept high until 50 seconds before landing. Even though the throttle back is accompanied by an airspeed reduction, the cooling rate still peaks at 34° C per minute, well abvove the recommended maximum of 28° C per minute. Incremental power reduction during the letdown reduces this effect.

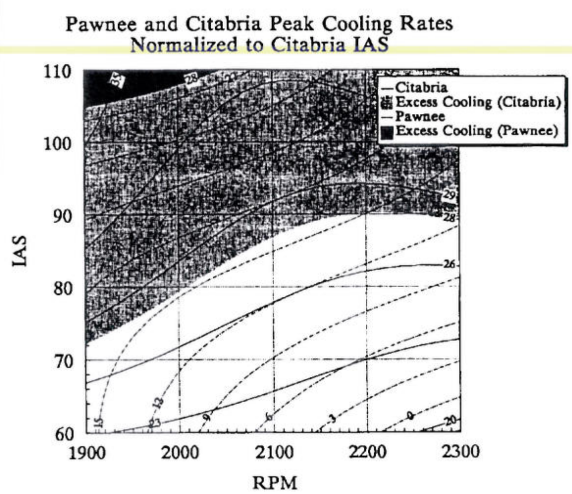

Figure 5. A comparison of the peak cooling rates of the Citabria and the Pawnee showing the extreme sensitivity of the Citabria to high IAS immediately after glider release.

same as those used for the Citabria, a period of initial observation of general club towing followed by a mapping of the letdown flight envelope to determine the optimum letdown. One of the problems we encountered was that this particular Pawnee has very large IAS position errors at low speed. This necessitated us calibrating it against our Citabria's IAS (it proved impractical to calibrate against a towed static bomb[1]), which is accurate if compared to the gliders at the field. Because of this, all IASs in this article have been corrected to the Citabria's IAS for the convenience of other operators whose Pawnees are blessed with accurate IAS, and Figure 1 contains the Pawnee/Citabria calibration data. One of our standard tow letdowns is shown in Figure 2. We use 100 mph IAS, 2000 RPM, and full flap as our target values and hold them until the circuit. Of note in Figure 2 is the fact that all the major temperature swings are in the middle and rear cylinders, the front cylinders are relatively unaffected.

Cooling and descent data were taken from 70 to 105 mph IAS and 1900 to 2300 RPM. After a normal glider tow to altitude, the Pawnee was stabilized as quickly as possible (generally about 10 seconds) at the desired IAS and RPM for the test point. The aircraft was flown wings level, full flaps, and ball centered for at least 1 minute before going to our club's standard letdown procedure. The FMS data recorded during this time allowed peak and average cooling rates and descent rates to be determined. Peak cooling rate was determined using an 11 point polynomial fit to the CHT data; average cooling and descent rates were taken from linear fits to the data. A total of 84 data points for each of the peak cooling, average cooling, and the descent rates were taken. These were then mapped onto a surface, smoothed, and contoured to produce Figure 3. The data in Figure 3 have standard deviations of 1.6°C for the peak cooling rate, 1.4°C for the average cooling rates, and 106 fpm for the rate of descent information (for those unfamiliar with statistics, this means that about 70% of the time the recorded data is no farther from the value given than one standard deviation). Our experience flying the test points leads us to believe that this variation is the result of the difficulty of holding the set IAS and RPM and is a useful guide to the safety margin that should be used when deciding on a letdown power and speed. As with the Citabria, the outside air temperature appeared not to be a factor in determining cooling rates within the temperature ranges in which we operated (41 to 86 °F or 5 to 30°C).

The data collected indicated that the letdown we were using was about optimal in terms of maximizing rate of descent and remaining below the allowable peak cooling rates, and because of this, we have left it unchanged. The 4-bladed propeller that this aircraft is equipped with adds about 200 fpm to the rate of descent, so operators with the standard two-bladed propeller will descend slightly slower than shown in Figure 3. One problem not apparent in Figure 2 or 3 is the Pawnee's ability to retain engine heat. We found that if a pilot was not sufficiently aggressive in the initial letdown, the engine remained hot until the circuit (good descent rates being possible at IAS and RPM settings that induce little cooling). This led to a cooling spike when the throttle was reduced in the circuit as illustrated in Figure 4.

Probably the most surprising thing for us was how different the cooling behavior of the Citabria and the Pawnee are. As shown in Figures 5 and 6, the Citabria is extremely sensitive to high IAS immediately after glider release, and above 2100 RPM the additional heat generated by the engine appears to be inconsequential. This means that the Citabria must be flown at reduced IAS for about a minute (until the CHTs are reduced) to avoid shock cooling, but after this handling is almost unrestricted. On the other hand, the Pawnee retains engine heat very well over the IAS range examined. Variations in RPM (and hence heat production) lead to cooling rate reductions regardless of the IAS, and overall the cooling rates at a given rate of descent are much lower than those for the Citabria. This leads to the need to cool the Pawnee fairly aggressively during the entire descent to ensure that sufficient cooling has occurred by the time it is necessary to reduce power for landing. If this is not done, the loss of heat generation on throttle back can result in shock cooling.

SOSA's 180 hp Citabria, C-GKXJ. This aircraft has cooling characteristics that contrast sharply with those of the Pawnee. Gentleman standing with KXJ is Mark Janoska.

We currently believe that this difference is due to details in the cowling of the Citabria and Pawnee. The Citabria has a relatively tight cowl with much less increase in cylinder-cowl clearance between the front and rear cylinders compared to the Pawnee, which has a relatively loose cowling with pronounced increase in cowl cylinder clearance toward the back of the engine. The reduction of the speed of the cooling air this causes over the Pawnee's rear and middle cylinders probably reduces the impact of higher IAS and allows more of the engine heat generated to be kept. We are continuing work on this in hopes of developing an expression for the peak cooling of a general cowling shape, but for now this interpretation should be considered speculative.

In summary, the cooling of the Pawnee is considerably different from that previously reported for the Citabria and demands a totally different letdown philosophy. Although the Pawnee is much more robust, there is a possibility of shock cooling in the circuit if sufficient cooling is not accomplished before throttling back. The variations we have found in the two aircraft used at our gliding club lead us to caution operators of other types to be very careful in extrapolating either the Citabria or Pawnee cooling profiles to different aircraft types, as the profiles appear to be very sensitive to the particular engine installation examined.

References:

1 R. Johnson, *Soaring*, Vol. 53, #5, pp 34-35 ■

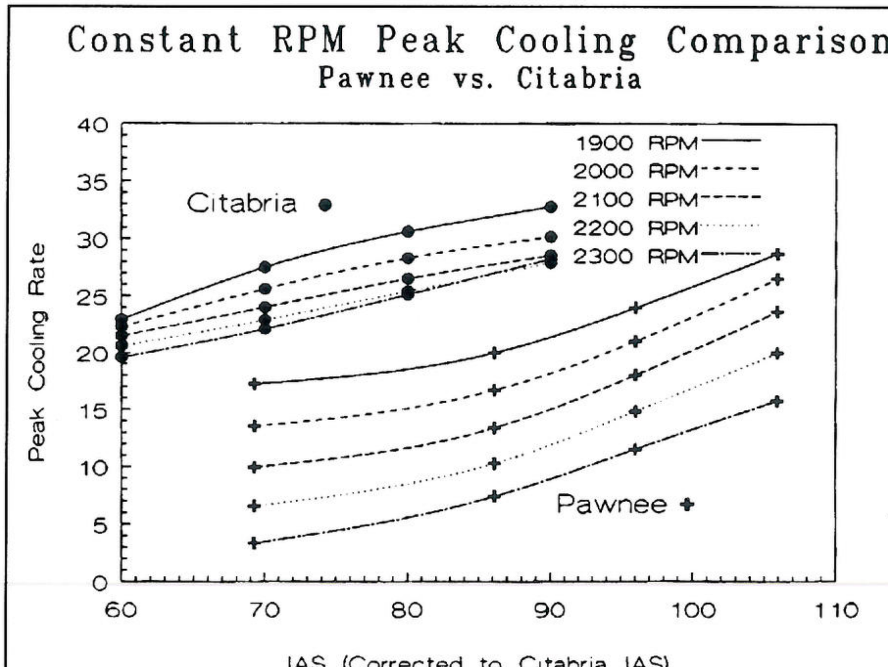

Figure 6. Another presentation of the data in Figure 5. This highlights the relative inability of the Citabria to retain heat generated by using higher power settings and the need to use aggressive letdowns in the Pawnee if cooling rates above 20° C per minute are to be achieved.