# Sizing the Induction Inlet in Aircraft Applications

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3-3-2009

Before we get into the details of inlet sizing, we should briefly discuss some terms that will be needed. The following is quick word about static and dynamic pressure. In aeronautical work we often deal with different forms of pressure. Pilots are exposed to static and dynamic pressure when the pitot-static system is explained. One additional concept needs to be introduced: Total Pressure. Total pressure is the sum of static and dynamic pressure ($P_t = P_s + P_d$). It is really just a measure of the total energy of the air. An important characteristic to understand is that static and dynamic pressure can be traded back and forth. The sum of the two will always equal the same quantity – total pressure. What this means is that air that was once stationary and is then accelerated will now contain some dynamic pressure. As a consequence, its static pressure will have dropped. The total of the two will still remain the same. If the air is again slowed to a stop, dynamic pressure will go back to zero and static pressure will rise back to its starting point.

Sitting stationary on the ground, total pressure is the same as static pressure. As we accelerate an aircraft through the air we are increasing the total pressure that is available to us by adding dynamic pressure. It is the dynamic content that we see in our airspeed indicator ($P_d = P_t – P_s$). We convert this dynamic pressure to static pressure to do useful work for us in our cooling and induction systems. By slowing the air we decrease its dynamic content and increase the static portion.

## Sizing Induction System Inlets

Sizing induction system inlets differs from the sizing of cooling system inlets due to the nature of what lies downstream. The cooling system will vary flow rate as a function of airspeed. Flow is a balance between the motive force provided by the aircraft moving through the air and the system resistance curve. The induction system, on the other hand, has a constant volume pump on the downstream end – the engine. This changes the situation in several ways. First, the volume flow rate is set by the speed and displacement of the engine. Losses in the induction system will not show up as reduced flow, but rather as reduced pressure or density in the engine's intake manifold. The engine manufacturers' publish performance charts assume that the engine is stationary on the ground. They are labeled 'zero ram'. One will note that the manifold pressure measured is lower than atmospheric. This is due in part to losses in the induction system. Additionally, a reduction is seen because the air in the induction system is moving. This reduces static pressure, which is the reading you see on a manifold pressure gauge. The combination can amount to one or two in-Hg. Now, on to sizing of the inlet:

Figure1, Induction Air Inlet

In a flying aircraft, especially the higher speed variety, we have a source of energy that can be utilized to counteract the losses inherent in the induction system. Here is the general approach. Take the desired engine speed and the engine displacement to determine the volume of air pulled in. Don't forget to divide by two for four-stroke engines. Now this volume flow rate is divided by the aircraft velocity. The result is the area that will produce zero differential between the inlet flow velocity and aircraft velocity. This size will regain some of the induction system losses since the air is not being accelerated through the inlet by the engine. Rather, the air is being fed in as fast as the engine can use it. There will still be losses in the induction system, but now the static pressure measured at the inlet will have returned to atmospheric. More can be gained by increasing the area further. If the inlet is made still larger then not all air approaching the inlet at aircraft speed can pass through the engine. The flow will slow down and static pressure will rise. One could turn the exact sizing into a real science project. Make the inlet too large and you end up adding external flow disturbances and drag to the air frame, so there are definitely diminishing returns. A middle-of-the-road approach is easiest. Let's walk through an example. Take an O360 at 2500 rpm. 360 in^3 x 2,500 rpm / 60 rev/sec = 7,500 in^3/sec. At 100 kts, or 2024 in/s, you end up with an area of 3.7 in^3 or 2.2 in diameter. If we increase this to an even

3 in diameter the inlet flow rate slows to 1061 in/s or 52 kts. The difference between these two speeds will show up as ram pressure in the form of ½ x density x vel^2. At high speed this can amount to quite a gain. For example, At 200 kts, with a 3 inch diameter inlet, the differential in the inlet comes to 148 kts or 1.0 in-Hg. This translates to 1.9 in-Hg above the zero ram condition found in the engine performance charts.

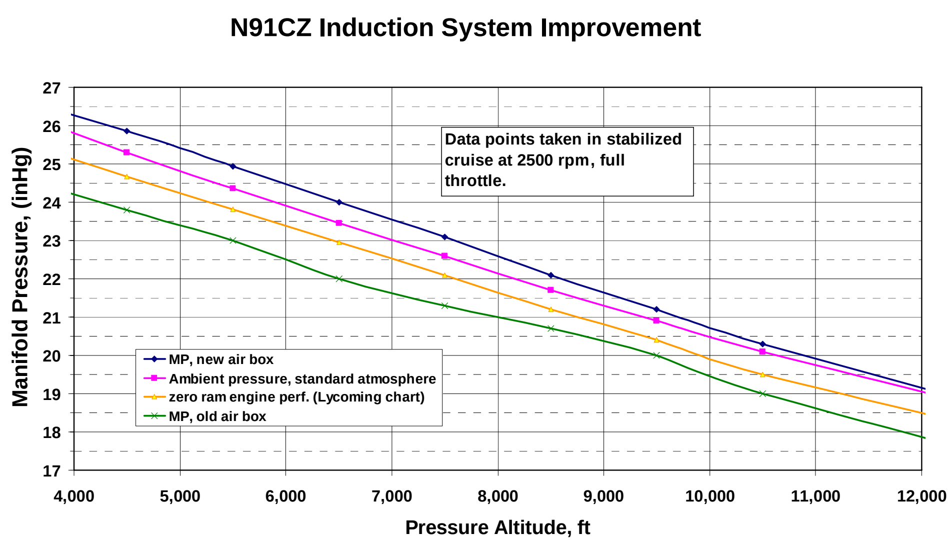


Figure 2, Induction System Improvement. The effect of capturing dynamic pressure and reducing the pressure drop across the air filter

As with any pressurized system, sealing is vitally important. Anything less than a positive seal will leak. By positive I generally mean clamped or bolted. Even small pressures create large forces when distributed over an area. This will move and distort parts and seals. What seals on the ground may no longer seal when flying. Unfortunately a small leak can negate all the effects of ram pressure recovery. In fact, in this case, it can pressurize the lower cowling which is undesirable from a cooling perspective. Figure 2 shows the capturing of ram pressure combined with an improvement in filter design. Manifold pressure is observed to be greater than ambient pressure. The increased manifold pressure resulted in a 10 kts increase in airspeed at higher attitudes. An intelligently sized inlet can provide a nice boost in aircraft performance.