The Risks of Maneuvering Speed Myths – Part 4

They say that all things come to those who wait!

At the end of Part 3 published in the August 2015 edition of Vitamin G, the official magazine of the Australian Aerobatic Club, I gave readers some homework:

"Are we allowed to apply full forward stick at Maneuvering Speed?"

I also promised to look at an actual flight envelope. In earlier parts of this article I had simply provided a sample flight envelope from the USA FAA's Handbook of Aeronautical Knowledge. Aircraft manufacturers seem shy about publishing such detail in their manuals so rely on a good general knowledge of flight envelope construction per the airworthiness regulations. For example, a manual may state the aerobatic limit load factors as +6/-3 G so you might reasonably expect those limits to apply generally. The observant readers would've noticed that in my sample flight envelopes the negative G limit is truncated above V_{NO}. That is a general characteristic of FAR 23 flight envelopes. At V_{NE} the negative limit load factor for an aerobatic aircraft is only about -1.0! Expect that to apply to your aircraft if it is FAR 23 certified. If not FAR 23 then expect more surprises, discussed later.

Let's have a look at the Flight Envelope for the most prolific aerobatic aeroplane in the world, the Pitts S-1S. The Owner's and Maintenance Manual states:

"The airframe of the Model S-1S has been verified for loads in excess of the Federal Aviation Agency Requirements for the stringent Aerobatic Category, at 1150 lb. gross weight. This means, in practical language, that at indicated airspeeds of 154 mph or less, you may apply sudden full aileron, rudder, or nose-up elevator deflection without exceeding the airframe minimum design loads. Sudden full nose-down elevator may likewise be applied at 106 mph indicated or less, without exceeding the design loads."

Well, that should answer your homework question! But let's go further as I'm an engineer.

The FAA's Advisory Circular 23-19A on certification of FAR 23 airplanes is very informative on this subject.

"What is the design maneuvering speed VA?

a. The design maneuvering speed is a value chosen by the applicant. It may not be less than Vs.√n and need not be greater than Vc, but it could be greater if the applicant chose the higher value. The loads resulting from full control surface deflections at V_A are used to design the empennage and ailerons in part 23, §§ 23.423, 23.441, and 23.455.
b. V_A should not be interpreted as a speed that would permit the pilot unrestricted flight-control movement without exceeding airplane structural limits, nor should it be interpreted as a gust penetration speed. Only if V_A = Vs.√n will the airplane stall in a nose-up pitching maneuver at, or near, limit load factor. For airplanes where V_A> Vs.√n, the pilot would have to check the maneuver; otherwise the airplane would exceed the limit load factor."

It is well worthwhile repeating those points and discussing them.

“The design maneuvering speed is a value chosen by the applicant.” Yes, it is probably not going to be that simple multiplier of stall speed that pilots believe it to be.

“V_A should ***not*** be interpreted as a speed that would permit the pilot unrestricted flight-control movement without exceeding airplane structural limits …”. This is the key to it so disregard what you have been told.

“For airplanes where V_A> Vs.√n, the pilot would have to check the maneuver; otherwise the airplane would exceed the limit load factor.” As we know, full elevator is permitted at V_A however it takes a finite time for the aircraft to respond so the pilot is indeed permitted to apply full elevator but must quickly bring it back to avoid the G building up. That applies to forward stick movement as well. There is not a separate V_A for negative Gs!

“The loads resulting from full control surface deflections at V_A are used to design the empennage and ailerons …”. That is the purpose of it so be mindful of how much control deflection that you apply for that reason.

Finally: “Amendment 23-45 added the operating maneuvering speed, V_O, in § 23.1507. V_O is established not greater than Vs.√n, and it is a speed where the airplane will stall in a nose-up pitching maneuver before exceeding the airplane structural limits.” You will find this in types certified after about the mid-‘90s so it means what it says and removes that disconnect between pilots and engineers.

Back to the Pitts S-1S.

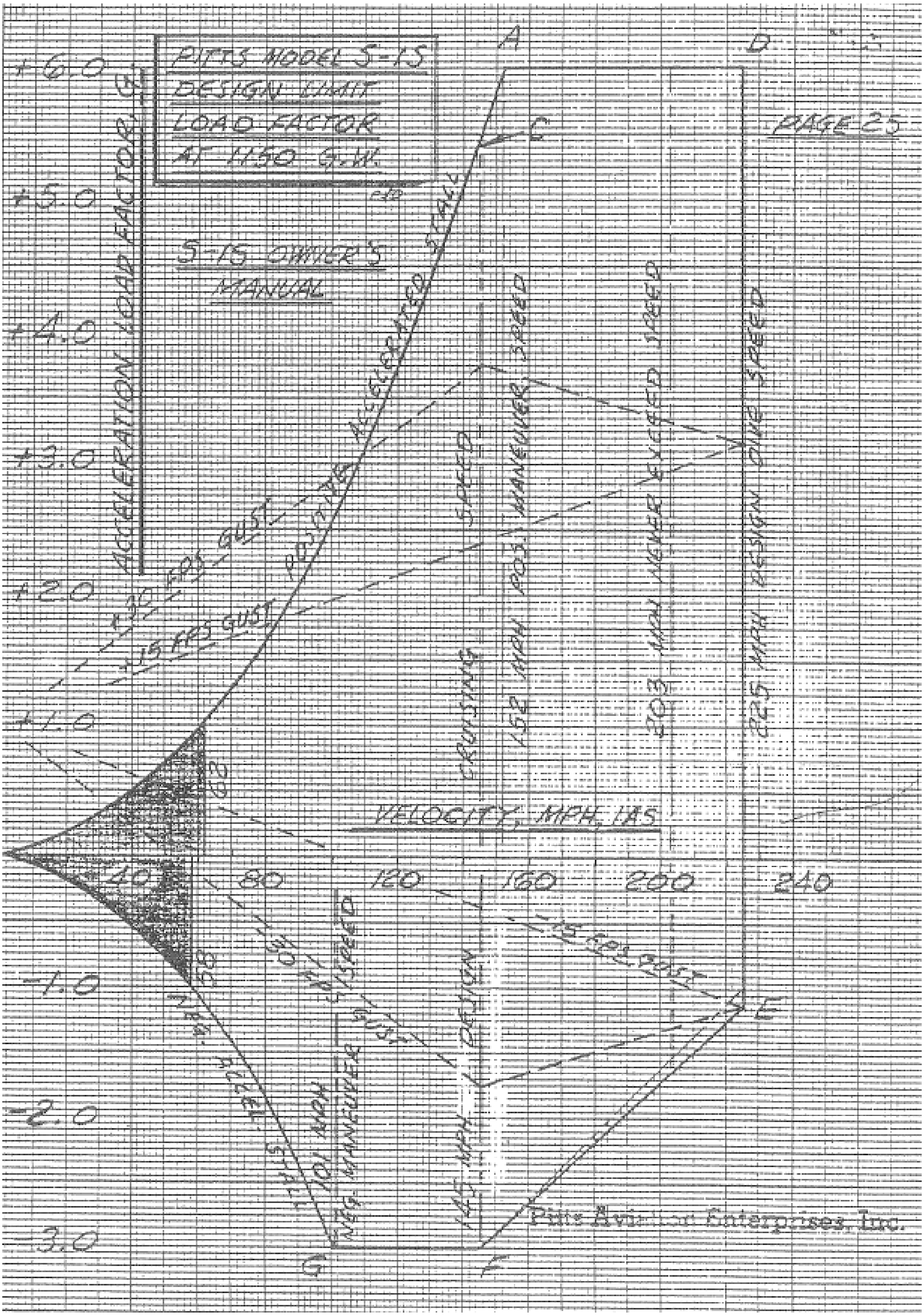
“These relationships are shown graphically on the V-G diagram of page 25.”

So, Pitts pilots have access to the full design envelope.

“If you compare the recommended entry speeds for various demonstrated maneuvers, shown on next page, with the V-G diagram, it should be clear that if you feel you need more airspeed than the tabulated values show, you are not properly performing the maneuver, and you may be overloading the airframe. Do not exceed the limitations shown on the V-G diagram; every maneuver in the Aresti ladder can be performed from combinations of the ones shown here.”

From the V-G diagram shown below you can see that above 145 mph (126 kts) the negative limit load factor progressively reduces from -3 to -1.15 at V_{NE}.

Another interesting feature is that the Design Cruising Speed (maximum structural cruising speed or maximum speed for normal operations) V_{NO} of 145 mph (126 kts) is less than the Maneuver Speed V_A of 152 mph (132 kts). Normally V_{NO} is greater than V_A but with a high drag (or low power) aircraft this is often the case but sometimes the designer elects to reduce V_A so that it equals V_{NO} which means that V_A is no longer that corner of the Flight Envelope. In the case of the Pitts S-2A the designer instead decided to increase V_{NO} so that it equals V_A.



As you can see the V-G diagram also shows the design gust loadings which are generally not significant for an aerobatic aeroplane.

If you fly an aeroplane which is not certified aerobatic per FAR 23 then you have other considerations:

- Aerobatic does not necessarily mean that it is +6/-3 – the figures may be much lower. +4.5 G was a common limit for semi-aerobatic category in Australia, NZ and the UK. Consider the Beagle Pup. 5 G was often used for American aerobatic aeroplanes long before FAR 23. Consider the Citabria.
- The positive limit load factor may also decrease at speeds above V_{NO}. Consider the early model Airtourers (the T-6 was certified to FAR 23).

Of course, FAR 23 represents the minimum so the designer is always free to choose higher design limit load factors than +6 and -3. The latest FAR 23 has been rewritten to be less prescriptive so it is even more important to read the AFM.

As for uncertified aircraft:

- Home-builts? A home-built Pitts S-1E may be identical to a factory S-1S or something entirely different.
- Limited category aircraft are generally not certified to any recognised civil airworthiness standards so may have their own surprises.