Vmin AND STALL SPEED

January, 2010

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For many years, pilots have assumed that published Vmin speeds for jet aircraft have been stall speeds like the ones they first learned, not realizing the speeds were in fact somewhat lower. The truth has not been obvious because pilots do not do full stalls in modern jet aircraft, instead relying upon the stick shaker (triggered by an angle of attack sensor) to indicate an impending stall. First generation jets, such as the B-707 and DC-8 may have been certified with 1g stall speeds (1g is the condition of not having any vertical acceleration relative to Earth). However, the B-727 and probably all following were allowed an interpretation of the regulations that Vmin was the minimum speed attained during a stall demonstration with less than 1g. This fact was first disclosed in an American Institute of Aeronautics and Astronautics paper (no. 74-956) by Foxworth and Marthinsen in 1974.

Upon disclosure, manufacturers first argued that it was too difficult to demonstrate 1g stall speeds in modern jet aircraft and supplied some chalk board presentations to prove their point. However, the Airworthiness & Performance Committee (A&PC) of the Air Line Pilots Association soon discovered the Mil Spec requirement for a 1g stall and that then became the focus of discussion which could not be ignored.

The major importance of the difference is the requirement to demonstrate a minimum stopping distance which required that the approach speed could not be less than 1.3 times Vmin. Because the stopping distance is factored to increase the minimum runway required for air carrier operations, the minimum demonstrated distance, depending upon the minimum allowed speed is significant for sales of aircraft. All other factors being equal, an increase in speed results in a squared percentage increase in stopping distance.

The fact that 1.3 Vmin was often promulgated as an approach reference speed instead of a minimum speed resulted in pilots being criticized for even minor deviations above the speed, resulting in numerous accident reports of overruns on wet runways which failed to recognize important factors and instead concentrated on the squared relationship of speed to stopping distance. With time, more reasonable margins for approach speeds (about 1.3 Vmin plus 10 knots as a reference) were allowed with recognition of the limitations of antiskid braking systems on wet runways. Grooved runways which provide nearly dry runway stopping capability became the standard.

The landing distance determined from certification is required by FAR 121.195(b) to be 60 percent of the runway allowed for air carrier operations while an additional 15 percent is required by FAR 121.195(d) for wet runway operations which is almost universally used by operators. This results in a factor of 1.92 times the certification number which means a pilot could use 92 percent more air distance and a deceleration rate factored by 1.92 and barely remain on a minimum length runway. Deceleration rates from certification are on the order of 0.50 g which would be a panic stop in an auto. That rate factored by 1.92 is 0.26 g, still a brisk deceleration rate.

This does not account for the fact that if the original intent of using a minimum speed of 1.3 Vmin 1g is required, the minimum length runway would be increased. Because normal operational landing weights are almost always less than maximum takeoff weights, any runway suitable for a takeoff is more than adequate for landing. However, aircraft don't necessarily land on the longest runway available. The fact that some of the safety margin is used up by a slightly higher approach speed should be considered for runway selection in marginal cases such as short, wet runways.

Another problem arose with recognition of the aircraft performance problems in windshears. Some advocated a procedure of training pilots to deliberately fly their aircraft to the stick shaker onset as a means of improving their ability to escape the effects of a severe windshear. The A&PC was adamantly opposed to this suggestion, unless ground impact was imminent, because the aircraft would be well up the back side of the drag curve at stick shaker speed where drag is substantially increased with a decrease in speed. The A&PC reasoned pilots should not stall above the ground or hit the ground with extra airspeed. Also, at the stick shaker speed, there is no capability to flare the aircraft, i.e., increase the angle of attack, to reduce the downward inertial vector (soften ground impact).

This became a point in discussions at the Congressionally mandated study by the National Research Council after the Pan American crash at New Orleans in 1982. The regulations required the stick shaker onset to be no less than 1.07 times Vmin, but if Vmin was less than 1g, what was the aircraft situation relative to a 1g stall when at the stick shaker speed? Consequently, the report "Low-Altitude Wind Shear and Its Hazard to Aviation" (National Academy Press, 1983--Library of Congress #83-63100) states on page 63 "The minimum speed at which level flight can be sustained is the 1g stall speed (Vmin 1g), which is typically 5 to 7 percent faster than the FAR stall speed." Subsequent Optimal Trajectory Studies of aircraft performance in windshears have proven that deliberate operation of an aircraft at the stick shaker angle of attack when ground impact is not imminent is a very bad idea[1].

Sometime around 1990, some aircraft manufacturers began to question the validity of not providing 1g stall speeds. Since all were going to try to sell to military customers they had to know these numbers, plus it was easier to determine and more consistent. However, the problem then arose of a competitive disadvantage to newer aircraft if they had to certify stopping distances based upon a minimum of 1.3 Vmin 1g, so the argument became one of what margin should be applied to the Vmin 1g speed to be equivalent to 1.3 applied to the old Vmin speed. The old numbers could have been reworked to provide the original intent of a 1.3 margin, but that would have resulted in requirements for longer runways--a good idea, but one that was not favorably considered. A Notice of Proposed Rule Making was published in 1995 by the FAA which finally made a change to FAR 25.125 effective 10/09/07 with a requirement that the certification approach speed may not be less than 1.23 V_{SRO}--a new definition in FAR 1.2 meaning "the reference stall speed in the landing configuration." FAR 25.207 was re-written to require, among other things, that the stall warning (stick shaker) could not be less than 1.03 V_{SR} (stall reference speed) and FAR 25.105 now requires that a stall reference speed may not be less than a 1g stall speed.

Because of the five year rule where the FAA allows a manufacturer to describe an aircraft and certify within five years under existing rules, and the derivative aircraft rule, allowing newer versions to certify under old regulations, operators and pilots may not see an aircraft very soon with approach reference speeds shown as 1.23 V_{SRO}. However, when it happens there will need to be some understanding and explanation that the new numbers are intended to be equivalent to the old numbers. Hopefully, the new numbers will be recognized as a certification minimum and not advocated as an operational norm.

1 For more information on this subject, see author's bibliography, especially references of Miele, et al which are reports on research funded by NASA Langely, Boeing, the State of Texas, ALPA and the Aviation Research & Education Foundation.