VAN'S AIRCRAFT
TOTAL PERFORMANCE

14401 Keil Road NE, Aurora, Oregon, USA 97002
PHONE 503-678-6545 • FAX 503-678-6560
www.vansaircraft.com • info@vansaircraft.com

SAFETY NOTICE 00114

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Subject:	Understanding RV Flight Limits
Affected Models:	All

Synopsis:

"Flies like an RV"
By Richard VanGrunsven

In sport flying circles, this phrase has come to represent a unique and very pleasurable flight experience. The Van's Aircraft line of kit-built planes has demonstrated a level of performance and flying pleasure that is highly prized by pilots. Their speed, power, control response, and maneuverability offer pilots flying enjoyment found in few other aircraft.

However, pilots of RVs and other low-drag planes need to be aware of the dangers of exceeding safe maximum speeds. RVs have low aerodynamic drag that contributes to their high speed and aerobatic performance capabilities. This low drag can also result in their easily exceeding design airspeed limits when descending.

THE NEED FOR FLIGHT LIMITS

Almost all airplanes have established flight limits determined by their structural qualities. As airspeed increases, forces on the airframe increase as a squared function of speed. The maneuvering acceleration (G) forces also increase as a square function of speed. Because airframes must be relatively light weight to perform well with modestly powerful engines, it is normal that aerodynamic forces can exceed structural limits when flown too fast or maneuvered too abruptly.

The most common established flight limits are **True Airspeed** and **G-loads** based on indicated airspeed.

EXCEEDING RED LINE SPEED LIMITS

When descending, even at shallow flight angles, low drag airplanes such as RVs can easily attain speed well in excess of those set as limits for safe flight.

To help explain this, let’s use the example of level flight thrust and drag. A typical RV-7 flying at a level flight top speed of 210 mph is developing 255 pounds of thrust, or pull, offsetting an equal aerodynamic drag force at that speed. If that RVs flight path is directed downward, by even a few degrees, the gravitational pull increases effective thrust greatly. While gravitational force is vertical, the wing’s airfoil converts that energy into a forward component of thrust at any descent angle.

To better appreciate the gravity effect, let’s say we take that RV, without considering any propeller drag or thrust effect, and point it straight down. In this condition its weight, say 1600 pounds, is effectively pulling the plane downward. Now, 1600 pounds of pull is obviously far greater than the 255 pounds required to fly 210 mph in level flight. In a matter of seconds, it will have accelerated from zero to 210 mph at which point its drag is 255 pounds.

But gravity is still pulling at 1600 pounds. minus the drag of 255 pounds, or 1345 pounds, so it continues to rapidly accelerate. Drag will increase as the square of the speed, and so will eventually equal the gravitational pull and the speed will stabilize, but at a level far in excess of Vne (maximum permissible). That is assuming that the airplane does not destroy itself first, which it almost certainly will.

More realistically, let’s see what happens in the same top-speed, level-flight scenario when the nose is lowered just a few degrees. A barely perceptible 2-degree descent angle at 180 mph will result in an altitude loss of 550 fpm. This means that the wing is no longer lifting 1600 pounds, and that translates to a thrust increase of about 55 pounds, which is enough to increase the speed to 220 mph.

While this math is not precise, you can only imagine how much speed will be gained very quickly in a 20–30-degree dive. A 30-degree dive will result in an effective 800 pounds of additional thrust. Obviously, the speed build up can be moderated somewhat by pulling the throttle back and reducing the engine/propeller thrust. However, beyond a certain relatively shallow dive angle, the airplane will exceed published red-line speeds even with the throttle at idle.

In flight it’s difficult for a pilot to gauge a descent angle. Let’s think about driving in mountainous areas. When highway signs caution a descent grade of 5% (about 5 degrees) the driver knows that they will soon need to not only release throttle pressure, but to apply braking to avoid “coasting” above a safe speed. The gravitational force is being translated into forward speed on the inclined plane of the roadway.

DANGERS OF EXCESSIVE SPEED

Aerodynamic/Structural Flutter

One fact that many pilots have trouble understanding is that the critical flutter modes in RV’s associated flutter speeds are measured in **true airspeed** rather than indicated airspeed. At higher altitudes, air density is less so that the dynamic forces on the airplane are lower at any given true airspeed. While airframe drag and engine power requirements are lower at altitude, structural flutter remains true airspeed dependent, which becomes more critical with increasing altitude.

Regarding flutter prevention, the operative word is "damping." When a control surface or flexible structural component is caused to move or is "excited," the damping ability of the surrounding air is relative to its density. Thus, the lower density air at altitude has less damping ability than at sea level for any given indicated air speed. This means that a moveable control or flexible airframe structure is less likely to re-center when rebounding from an upset. Because of the lower air density, the control surface is more likely to overtravel center and repeat the upset cycle. This can become a self-perpetuating cycle of increasing amplitude and force. It can increase in amplitude and frequency so instantaneous that a pilot has no time or ability to take corrective action and structural failure can result.

The relation off the center of mass of a control surface to the hinge point or the center of mass of structure to the elastic center (the point about which structure will twist under load) creates a moment (or torque) that will drive flutter. The flutter resistance of aircraft control surfaces is dependent on their static balance. Altering the static balance of a control surface through the addition of excessive paint or counterbalance weights can affect the speed at which flutter occurs. The flutter characteristics of primary structures, such as wings, can unintentionally be altered by addition of weights such as fuel tanks in locations that have not been tested.

Though aerodynamic flutter is not intuitively easy to understand, "never exceed" true airspeed limits must be adhered to.

The important message to pilots is that almost any time (other than in controlled aerobatic flight) the aircraft is pointed down, throttle should be reduced. This needs to become instinctive for the pilot so that when, particularly when, this nose-down attitude is unplanned or exceeds the intended pitch-down attitude, throttle needs to be retarded appropriately.

Exceeding Structural G Load Limits

RVs have high top speed relative to their stall speeds, thus a high speed ratio—the range of usable speeds is significantly greater than most common aircraft.
At clean (flaps up) stall speed a plane can support only its weight, or 1 G. Since the wing's lifting ability increases as the square of speed, at twice stall speed the wing can generate four times as much lift as at stall speed. Thus, pitching to a stall angle of attack can subject the airframe to a 4 G load.

For an aerobatic-category aircraft with a 6 G design limit, the maneuvering speed is 2.45 times stall speed. RVs and other fast airplanes have top speeds much higher than their maneuvering speeds. An aircraft's maneuvering speed is the highest speed at which full control input can be applied without exceeding design structural limits. Thus, excessive control input at any speed more than maneuvering speed can result structural overload. At speeds near or greater than cruise speed, excessive control inputs in RVs can impose structural loads far in excess of design limits. Safe flight above maneuvering speed requires pilot-moderated control inputs. Safety is pilot-limited.

Vne is based on both true and indicated airspeeds. The dynamic pressure exerted against the surface of the wings when maneuvering – such as when pulling out of a dive – is dependent on **indicated airspeed**. The **true airspeed** (at least for RVs) is linked to flutter. Modern EFIS systems allow both true and indicated Vne to be configured at the same time. The worst-case limitation – true or indicated – is automatically displayed on the airspeed tape. Consult your EFIS installation manual to configure both appropriately.

AEROBATIC FLIGHT

Aerobatic flight, carefully planned and executed, can be accomplished within the safe operating limits of aerobatic-qualified RVs. However, aerobatic flight with unusual attitudes and aggressive maneuvering is a regime where flight limits could be unintentionally exceeded. Any pilot engaging in aerobatic flight needs to be aware that the probability of exceeding flight limits is geometrically greater than in routine non-aerobatic flight. Simply stated, safe aerobatic flight requires training, planning, and discipline.

Historically, airplanes used for aerobatics were open cockpit biplanes. They were slow and maneuvered in small spaces, thus endearing them to airshow spectators because they could easily remain in “show center” for all to see. Because of their high-drag configuration, exceeding critical structural speed was not usually an issue because they did not accelerate quickly, even in steep dives. From the pilot’s perspective, a vertical dive at full throttle might be held for 10 seconds before recovery or throttle reduction was needed to remain within safe speed limits.

In a similar situation, an RV might accelerate to its critical speed in only 2 seconds. The RV pilot’s reaction time must be much quicker. The pilot’s planning must be better. For this reason, the “self-taught” approach to aerobatics can be very dangerous. Bad things can happen too quickly. Per the above flutter and maneuvering acceleration cautions, waiting too long to initiate dive recovery could result in overspeed and airframe flutter. In an effort to avoid rapidly increasing speed in a dive, pulling up too abruptly could exceed structural G-limits. There is only one way to engage in aerobatics: the right way, through trained and practiced control of speed, attitude and engine power.

Many years ago, I wrote a comprehensive paper on conducting aerobatic flight in RV kitplanes, “An Aerobatic Epistle” (See SN-00115). It includes explanations on how to do, or not do, aerobatics in RVs.

DOG FIGHTING

In a word, don’t.

One of the most glamorized forms of flight is simulated air-to-air combat, commonly called “dog fighting.” Its appeal is perhaps an extension of the ancient gladiator battles, sans the bloodthirsty stadium audiences. Unfortunately, most common light aircraft are not suited, either in maneuverability or strength, for dog fighting, nor are pilots trained or disciplined to do so. Many eager pilots have tried, sometimes with disastrous results. Impromptu dog fighting can be described as unplanned, unscripted, and uncontrolled aerobatics. Many things can go wrong in a matter of seconds.

Some of these are:

Exceeding structural limits. Most military aircraft engaged in aerial combat fighting were built to withstand high speeds and high maneuvering G loads. This is not true of light airplanes, even those designed and rated for sport aerobatics. During impromptu dog fighting the unspoken objective is to get the opponent aircraft in your imaginary gunsight and keep it there. Thus, excessive air speeds, G-force, or extreme (unrecoverable) attitudes can too easily be encountered by aggressively pursuing or evading the opposing airplane.

Collision with other aircraft. Perhaps not likely, yet possible~~.~~ When neither participant knows what the other's intent is, flight paths can conflict; collisions can occur.

Collision with the ground. Sure, you would never intentionally engage in dog fighting at low altitude. However, most planes will lose altitude while maneuvering under high G-load conditions. Imagine the classic steeply banked, high G, turning-tail chase. Soon enough you're in the trees, or nearly so.

Loss of control. Depending on the stability of the aircraft involved, it is entirely possible to enter a stall/spin while trying desperately to evade your adversary. Again, with your primary objective being anything but routine straight-and-level flight, bad things can happen.

Exceeding speed limits. You could easily exceed speed limits in an attempt to either elude your adversaries in a steep dive or in attempting to catch them as they attempt to evade you.

Exceeding G-limits. Through attempting to acquire or hold your aggressively maneuvering adversary in your "gunsight" you could easily exceed structural G-limits. *The lesson to be learned from the risks of dog fighting also applies to any spontaneous unplanned abrupt maneuvering or control application. Limits can quickly be exceeded.*

THE KILLER ROLL

It's quite possible that the median non-aerobatic pilot would surmise that the simplest and safest aerobatic maneuver would be a roll. Little altitude variation should be experienced, nor should any significant speed or g-load be encountered. Though this should be true, **rolls in RVs have probably resulted in more fatal accidents than any other maneuver.**

Many have been from loss of attitude and altitude control; crashing into the ground. Others have resulted from airframe failures caused by excessive speeds resulting from loss of attitude and power-application control.

When I first developed and began giving sales demonstration rides in my RV-4 over 40 years ago, I was eager to show how easily and safely aerobatics could be performed. I would demonstrate a positive-G roll that that was smooth and enjoyable. It was so easy to perform that I felt any pilot could do it with simple steps and would further endear them to the plane. The results were overwhelmingly negative, so I stopped doing that. Why was it so easy for me but not for them?

Many years ago, a patient flight instructor explained to me how to land a plane and demonstrated it. When I tried, it didn't work as well on the first, second, third, etc. tries. Obviously, the same was true for the simple positive G roll—practice is necessary.
It is actually easier to perform a roll than a good landing. But it does require practice and fine tuning of control use. I could perform a safe, smooth roll because I had practiced

hundreds of them, not because I was a superior pilot. As with landing a plane, it requires some level of repetition to master the visual and tactile cues and apply appropriate control inputs.

A roll could easily be viewed simply as an extension of a banked turn. You just continue rolling into the bank until you've completed 360 degrees of banking. Maybe this would work in fighter jet, but it doesn't in an RV-class airplane.

Rolls are usually entered at or above cruise speed. For an airplane with positive stability, the C.G. is forward of the center of lift. In a bank, the nose will lower. Inverted, the nose will drop even faster, and speed will increase rapidly. The spontaneous reaction of a non-aerobatic pilot when inverted with the nose dropping is to pull back on the stick to raise the nose and arrest the descent.

When inverted, this just lowers the nose to an even steeper descent angle and causes an even more rapid speed build up. Remember the discussion of rapid speed increase when in even a shallow dive? Now we're in a steep inverted dive entered at an already high cruise speed with a spatially confused pilot. Even if power is reduced, exceeding red-line speed is probable.

Point being: If someone doesn't know how to properly enter a roll, they probably aren't prepared to safely recover from a failed roll.

If executed properly, RVs can perform rolls (and other aerobatic maneuvers) easily and safely in a manner well within **design limits**. Quality training is the key.

Don't be led into aerobatic experimentation by airshow examples or encouragement from self-appointed airport wags.

FLIGHT INTO INSTRUMENT CONDITIONS

Unintended flight into instrument conditions (IMC) can easily lead to loss of attitude awareness, unusual attitudes, then flight overspeed. With the probable onset of vertigo, the pilot could easily overspeed and then overstress the plane in an attempt to pull up and reduce speed. Without knowing which way is up, "results may vary."
Successful IMC flight requires several factors, including pilot training, pilot proficiency, aircraft equipment, and planning. The worst case is an unequipped aircraft and an untrained pilot experiencing an unplanned entry into IMC flight conditions.

Most RVs built within the past 20 years are equipped with EFIS instrumentation and autopilots. The attitude information and flight stability that these features offer can be of great help to pilots flying in IMC conditions. However, the caveat is that the pilot must be trained and proficient in their use. Particularly in the instance of inadvertent entry into IMC, the pilot doesn't have time for a methodical refresher course before loss of control can occur. That said, current accident statistics indicate a lower incidence of IMC fatal accidents than in the past, but this is a phase of flight that should be taken seriously and addressed with training and repeated practice for the pilot to be competent and comfortable.

SUMMATION

RV flight limits have been established based on sound structural and aerodynamic criteria. A reasonable pilot exercising disciplined pilotage can enjoy all that his aircraft has to offer, including aerobatics, and easily remain within specified limits. Fly smart and safe.

Make a logbook entry indicating compliance with this service document per the requirements of the controlling authority/agency.

Place a copy of this notification in the back of the maintenance manual for your aircraft. Add the name and date of the service information to the Addendum Documents List at the front of the Maintenance Manual.

If you are no longer in possession of this aircraft, please forward this information to the present owner/operator and immediately notify Van's Aircraft, Inc. via email at registrations@vansaircraft.com. Please include the new owner's contact information and date the aircraft ownership transferred.

Information regarding establishing/transferring aircraft ownership, registration and licensing is available at: https://www.vansaircraft.com/qr/transfer-of-ownership/