

Vortex Ring State

A USHST Airmanship Safety Bulletin (Part 1)

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In 2008, the pilot of a Bell 206B ran into unforecasted weather conditions sixteen miles from his destination and decided to turn around. As weather further deteriorated, he smartly decided to land in a field near a ridgeline crossed by a power line. Unfortunately, as the pilot circled in toward the field, with strong tailwinds on the leeward side of the ridge, he descended vertically too fast. And according to the NTSB, the on-board GPS recorded a 1000 ft/min descent rate. The pilot found himself in a Vortex Ring State (VRS) and misdiagnosed the vibrations and shaking of the helicopter (characteristics of VRS) as a maintenance issue. The helicopter's engine did not possess the power necessary to arrest the high descent rate. The pilot survived the subsequent ground contact but sustained serious injuries. This accident is a classic example of VRS.

ENCOUNTERING VRS

Conditions for encountering VRS are straightforward – the helicopter must descend vertically or nearly vertical at roughly the same speed as the vortex wake being produced by the rotor, or roughly, 60 percent to 70 percent of the hover-induced velocity. According to Albert Brand, Senior Technical Fellow for Flight Technology at Bell, there are at least two ways for this to

happen. First, the slow-flying pilot can simply choose to lower the collective and create such a descent rate – let's call this commanded VRS (whether deliberate or inadvertent). Second, the pilot may be at an altitude where the helicopter has insufficient power to hover (or fly slow). In this case, the increasing power demand of low speed flight will force an uncontrolled descent rate to develop, which may lead to inadvertent VRS.



DESCENT RATE NEEDED TO ENTER VRS

Nick Lappos, a Sikorsky Aircraft Senior Technical Fellow for Advanced Technology and former Chief Research and

Development Test Pilot, claims true VRS is experienced at about 70 percent of the downwash velocity. The characteristics of a rotor's design (particularly its disk loading- or thrust per unit area of the rotor disk) make it easy to calculate the speed of the downwash, and it is different for each helicopter design. Lappos is on record stating the "greater than 300 feet per minute (fpm)" VRS onset guideline presented in many pilot publications is a myth. He contends (and his hypothesis is consistent with DoD / NATOPS guidance) the rate needed to enter full VRS – even in the lightest helicopters – requires descent rates of 700 to 1000 fpm. In larger (heavier and higher power) rotor driven aircraft, the descent rate required could be much higher (Blackhawk -1500 fpm; and V-22 – 2000 fpm for example). Tim Tucker, Chief Instructor at Robinson Helicopters agrees with Mr. Lappos's hypothesis on VRS, stating helicopters with low disk loading (the R-22 for example) will experience VRS at lower descent rates.

WHAT HAPPENS IN VRS

Al Brand posits if you descend at about 60 percent of the hover-induced velocity, you will place the vortex wake in a situation where it accumulates beneath the rotor with each turn of the rotor. The accumulation of the vortex wake increases the rotor inflow (i.e., down flow through the rotor increases in spite of the descent rate). More rotor inflow reduces the rotor blade angle of attack, which can (initially) be compensated for by an increase in collective pitch. However, the increase in collective does not stop the accumulation of the tip vortices into the vortex ring. As more descent rate ensues, more collective is applied, but the rotor finally loses the battle. At this point, the rotor loses some thrust and falls through the ring emerging with the ring above the rotor

at some higher steady descent rate at 1-g thrust. With a vortex ring above the rotor, collective becomes ineffective at arresting descent rate as it merely closes the gap between the ring and rotor, preventing thrust from increasing.

VRS is an aerodynamic interaction phenomenon between the rotor and its vortex wake. You do not have to be skilled to get into VRS – under predictable circumstances, VRS will find you, and for this reason, you need a plan to get out of it. A technique called the *Vuichard Recovery* is the best available for a single main rotor helicopter.

*For more information on this subject, refer to the USHST Airmanship Bulletin on the *Vuichard Recovery* at www.uskst.org



ARE VRS ACCIDENTS COMMON?

So how common are VRS accidents? The United States Helicopter Safety Team (USHST) analyzed over 1000 U.S. commercial helicopter accidents that occurred between 2000 and 2017. The Team could only find three accidents where VRS was the lead factor (NYC06LA062,

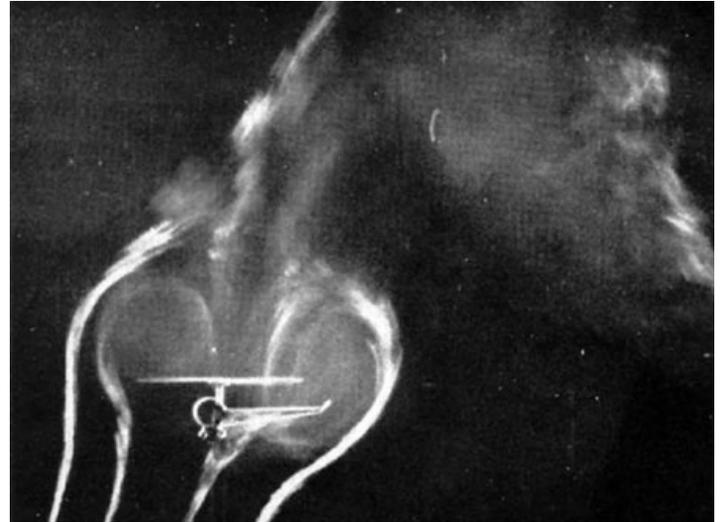
DEN02GA085 & ERA16LA159), and two accidents where VRS may have been a contributing factor (ERA13LA018 & LAX08CA138).

USHST ANALYSIS OF VRS and POWER MANAGEMENT ACCIDENTS

VRS is included in the USHST accident category, *Loss of Control – Inflight (LOC-I)* – which was the cause of approximately 18 percent of 104 fatal U.S. helicopter accidents analyzed by the USHST in the years between 2009-2013. Among these LOC-I events, and of much greater concern than VRS incidents, a power available limitation was a factor in 37 percent of them. In seven out of 19 fatal accidents attributed to a power available limitation, the pilot exceeded either a structural limit or an environment induced performance limit. In these instances, a pilot is more likely to run out of power on takeoff trying to clear trees (N1 topping), or run out of power during an approach, or exceed the power limits while trying to hover out-of-ground effect, or run out of power trying to cross a mountain pass. As long as the power limitation did not result in an uncontrolled descent rate at low forward airspeed, such accidents would not be associated with VRS. Otherwise, all bets are off. Insufficient power to hover is a recipe for initiating VRS.

AWARENESS OF VRS AND HOW IT RELATES TO POWER MANAGEMENT ISSUES

A lot has been written about VRS, including the recommendation to not exceed a 300-fpm descent rate (which admittedly is an excellent rule to use to stay out of trouble on



any type of descent or approach). On check rides, examiners like to discuss VRS (currently referred to as *Settling with Power* in the FAA's Helicopter Flying Handbook (HFH) FAA-H-8083-21A, Practical Test Standards – or PTS, and the U.S. Army's TC 3-03.4 – Fundamentals of Flight). We spend a good portion of our table time during the oral explaining this aerodynamic phenomenon. Apparently, this awareness has paid off, since accidents directly attributed to VRS in the U.S. are uncommon. There is definitely a cause and effect relationship between VRS and a power available limitation. It is easy to exceed the limits of the helicopter's performance, but not necessarily get into VRS.

USHST analysis has consistently shown that power or performance management and exceeding limitations accidents comprise 20 percent of all helicopter accidents (fatal and non-fatal) each and every year. With this startling statistic in mind, perhaps flight instructors and examiners need to spend more time teaching sound power management practices and the effects of exceeding a power available limitation. Call the thing that is not vortex ring what you

like – Power Available Limitation – Inadequate Power Management – Settling with Insufficient Power – Power Settling – Insufficient Power to Maintain Altitude – or simply – Power Management. But we need to stop using the catchall and confusing term – *Settling with Power* – to describe both issues.

THE TERM “*SETTLING WITH POWER*” IS BEING SLOWLY PHASED OUT

The term *Settling with Power* is gradually being eliminated from publications when speaking about VRS. In 2006, Transport Canada struck the term from their Helicopter Flight Training Handbook, and they explain why. The FAA will do the same and use *Vortex Ring State (Settling with Power)* in the next revision to the HFH and new Airman Certification Standards (ACS) series for Rotorcraft-Helicopter.

In Part 2 of this Airmanship Bulletin, we will discuss Loss of Control – Power Management and Exceeding Limitations accidents, which are the cause of nearly 20 percent of all helicopter accidents.

**NOTE: As a result of the USHST fatal accident analysis mentioned above, several Helicopter Safety Enhancements (H-SE) were developed to address many of the issues covered in this two part Airmanship Bulletin: H-SE 124 – Understanding of Basic Helicopter Aerodynamics; H-SE 116 – Improve Make/Model Transition Training; H-SE 117 – Competency-based Training and Assessments in Initial Pilot Training; and H-SE 119 – Training, which includes special emphasis on preflight performance planning calculations, the potential consequences of poor preflight performance planning, and using performance planning in risk assessment and mitigation.*

