The H/V Curve

What They Didn’t Teach You in Ground School

MD500 flares at the bottom of an autorotation, trading airspeed energy for rotor RPM just prior to touch down

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Call it what you want: "H/V (height/velocity) curve," "dead man's curve," or even "limiting height-speed envelope," for those who like sophisticated phrases. The "dead man's curve" term is probably a carryover from our fixed-wing brethren. The helicopter industry generally accepts the simple reference of H/V curve. The inside of the curve is the area from which it will be difficult, or nearly impossible, to make a safe landing following an engine failure (if you are in the same conditions depicted with respect to airspeed, height above ground, weight, and density altitude).

The H/V diagram is a staple in the helicopter arena, but sadly students and instructors alike misunderstand the basic concept of the curve. So, let us take a look at what it is and how it is developed.

Rarely, if ever, will the sight picture look like this when a real engine failure occurs

What is it?

The H/V diagram/curve is a chart showing various heights (AGL) with a combination of a velocity (indicated airspeed) where a successful autorotation *and* landing is, or is not, likely possible. This magical combination of numbers yields two major regions on the chart: the area above the "knee," and the area below the "knee." These areas are what actually plot much of the curve. During initial helicopter certification, test pilots evaluate several characteristics of the helicopter that help determine the H/V curve. These factors include the helicopter's initial response to a power loss, steady-state descent performance, and power-off landing characteristics and capabilities.

Unknown to many, the development of the H/V curve and its associated number combinations is based on pilot minimum skill level. I call it "minimum," but for those letter-of-the-law followers it is actually termed "normal" skill level. So, in a perfect world, this means if the engine fails while I am going 'X' KIAS, and at 'X' height, a pilot at a minimum (or normal) skill level should be able to make a successful autorotation … and hopefully some resemblance of a successful landing.

How do we define pilot normal skill level? That is a question I, and many others, cannot answer. Many feel that the current practical test standards (PTS) are somewhat lacking and may not necessarily be cultivating the necessary skill levels required.

Performance or Emergency?

To delve into this quandary, let us recap the typical sequence of an autorotation training exercise. The newly minted instructor has the student line the helicopter up with the runway so that the power-recovery phase of the autorotation will occur as closely to the runway numbers as possible. Sound familiar? You know what I'm talking about, the "3, 2, 1, roll-off power," etc.

It is the same thing with an 180-degree autorotation, where the student is taught where to "fail" the engine based on tailwind strength and land at the spot within the practical test standard. Is there really anything "practical" about it? What if an engine failure occurs in the real world and the only spot you have is 600 feet directly below you? Could you get there … *safely*? What about engine failures at night with the same situation? The only place to go is directly below you or just out in front of you. If you remember anything from this article, remember this: Autorotations are like fingerprints; no two are *exactly* the same.

In the training scenario above, what exactly is being taught? For the most part, what is being conveyed is to get to that perfect spot: I need my engine to quit right about here. In my experience, engine failures are horrible with their schedule and usually do not make an appointment. The current training trend observed in many flight schools can result in less than desirable results. Is it this one-size-fits-all training style that develops the elusive normal skill level? I will be the first to admit that we all have to start somewhere, and everyone needs to learn the basics of a proper autorotation entry and subsequent autorotative descent. However, learning how to *work with what you have* in order to get to a spot is paramount. During primary training, many hours and lessons are spent on teaching basic approach angles: shallow, normal, and steep. Why can we not teach the autorotation as just another way to make an approach, all the while using various techniques to alter the landing spot? Part of this reason may be because the industry generally trains to the PTS.

Having said that, many will point out that the "straight-in" and "180" autorotations listed in the PTS is actually found in the Area of Operation listed in the Performance Maneuvers section, and they are correct with their assertion. However, it is important to note that the standard requires that the applicant establish "proper aircraft trim and autorotation airspeed" within a specified tolerance. (Private standards are ±10 knots and commercial standards are ±5 knots.) Moving on to the area of operation entitled "Emergency Operations," you will find a task entitled "Power Failure at Altitude." This is where the DPE will introduce the "surprise" engine failure. The problem here is that the applicant is expected to once again establish proper aircraft trim and autorotation airspeed within a given tolerance. So, in that power failure at altitude on the checkride—or in the event of a real engine failure—one can only hope that the pilot has a suitable landing place that is achievable by following a standard.

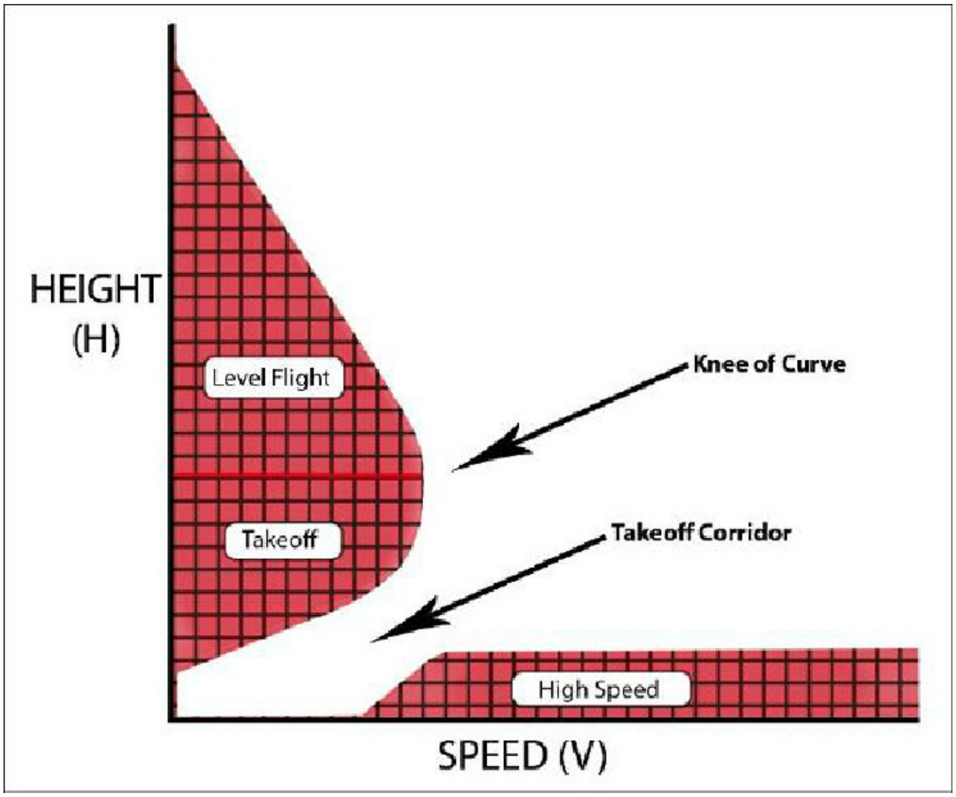
More H/V Curve Development

When test pilots are developing the H/V curve for a specific helicopter, the testing is done in very defined environments and conditions. The test is conducted at MGW for sea level and max OGE weight, with the lesser of aircraft maximum altitude capacity or 7,000 feet density altitude (DA) with 2 or less knots of wind, with the landing portion being conducted to a smooth hard paved surface. Many modern helicopters can hover OGE at maximum weight at 7,000 feet DA, so that is normally where the testing is done. Maybe this less than ideal scenario is what helps define the elusive minimum (or normal) pilot skill level, in the hopes that the average pilot will not often be found in these conditions.

Another tidbit of importance to mention is that when H/V curve testing is being done, it is accomplished by a throttle chop and not an actual flameout. As best described by my friend Pete Gillies of Western Helicopters, "There is a world of difference between chopping the throttle to idle versus flaming out the engine." One of my favorite helicopters, which I currently fly for a living, develops up to 35 horsepower during the final pitch-pull during the landing, and this makes a big difference compared to a landing with the engine gone away completely. Piston-powered helicopters, on the other hand, can go all the way to the landing without the engine contributing any power at all to the rotor system. This gives the pilot a much more realistic feel for a real engine failure. In turbine helicopters, only the Lama, Alouette, and Gazelle will provide similar results as their piston-powered brothers, because of their centrifugal clutches.

In addition to the testing conditions previously mentioned, the development of the H/V curve also includes an "intervention time" in an attempt to mimic the surprise factor encountered in real engine failures. This intervention is measured in terms of seconds (or lack thereof), depending on where you are located on the curve.

Maintaining proper hover height is critical in smaller training helicopters with low-inertia rotor systems.



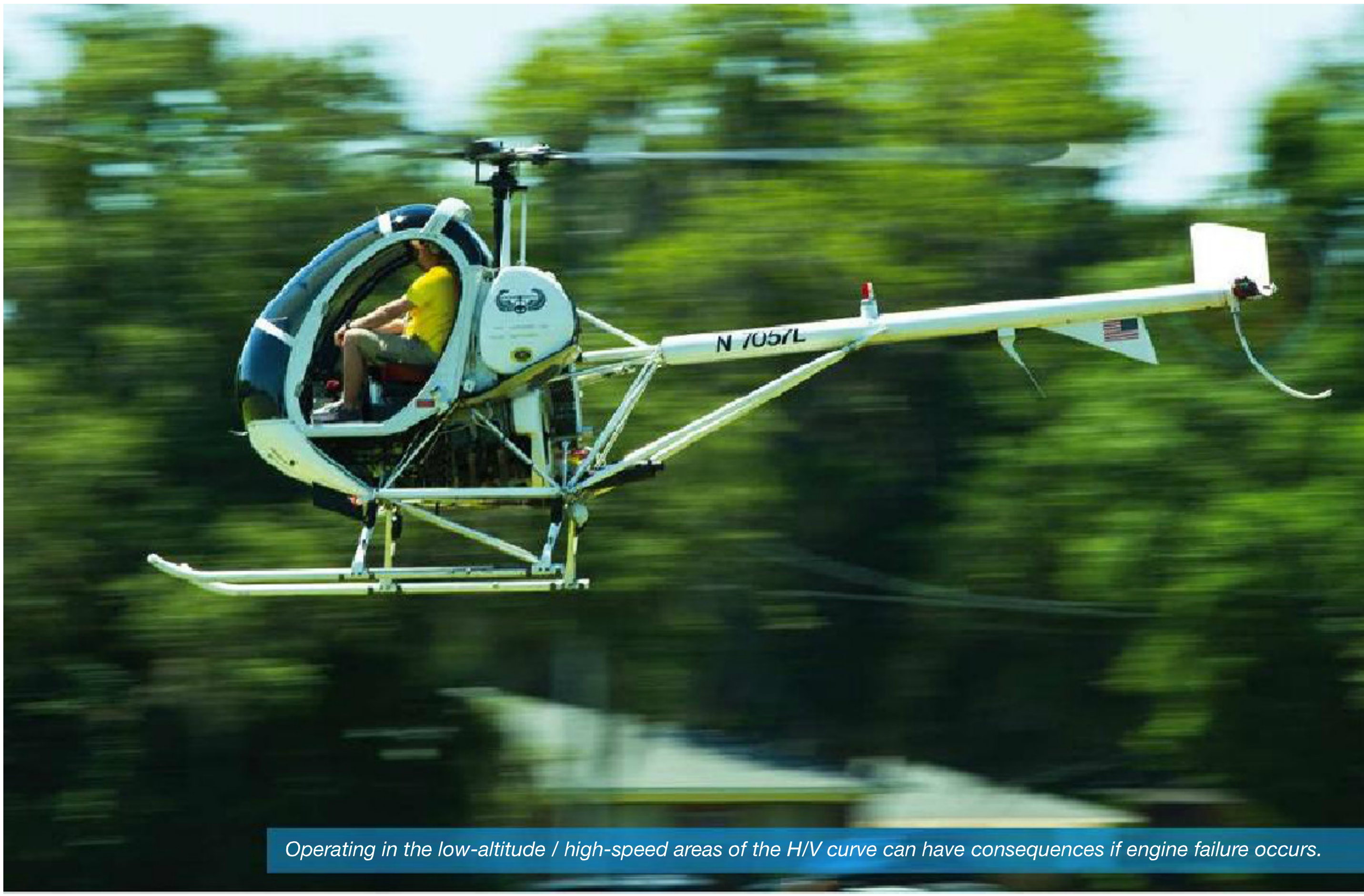
The civil certification calls for a 1-second intervention at an area *above* the "knee." In essence, during testing and certification, the throttle is rolled to idle and a "one-thousand-one" count is initiated. In a recent interview with experienced test pilot Shawn Coyle, he recounted, "The pilot's one hand is on the cyclic and feet on pedals, (sounds reasonable) but the pilot's other hand isn't on the collective." This standard applies to your basic helicopter certified under FAR Part 27 standards. Although it is assumed you won't have your hand on the collective above the "knee," the standard requires that the power be set for level flight at any specified airspeed. Military certification standards are a bit different, requiring a 2-second intervention before any pilot action.

Flight-testing for areas *below* the "knee" have no intervention factor, as it is assumed you will be at full or takeoff power with *all* feet and hands on controls. During certification, the RRPM in autorotation is set for minimum power off of Nr, with the collective full down.

The H/V curve is defined and built by determining the high hover point (HHP) and the low hover point (LHP). Determining the HHP starts from a safe area like 1,000 feet AGL and 60 KIAS. An entry is made from that condition and the reaction of the helicopter is noted. The next entry will be at a slower airspeed, and so on, until zero groundspeed is reached. Although the kinetic energy from airspeed is very low, the potential energy from height enables the ready conversion of potential to kinetic (i.e., airspeed for normal). Certification calls for a maximum nose down attitude of 20 degrees, which results in a steep dive, ending with a rapid flare at the bottom. Moving down from 1,000 feet, the height is decreased in small increments until the minimum height for safety is found. At this point, the maneuver is continuous: Entry is followed immediately by nose down, and as soon as the normal airspeed is reached, the flare is employed.

The "knee," or middle of the curve if you like, can be a difficult spot; potential energy (height above ground) is low and kinetic energy (velocity) is low or medium, at best. This is usually around 100-150 feet AGL and 40-60 KIAS. Operation in this area typically requires a slight reduction in collective, and proper skid alignment with the direction of travel. There is not always enough speed to make an effective flare, nor enough height to trade for airspeed.

The energy-deprived LHP is tested by keeping the collective fixed during the



Operating in the low-altitude / high-speed areas of the H/V curve can have consequences if engine failure occurs.

entry, and only raising it to cushion the touchdown. The reason for this is that experience in real engine failures shows that there is not enough time to lower the collective and then raise it. The only energy available is that which is available in the rotation of the blades.

Knowledge is Power

So how do we tie all of this knowledge together? Some agree that the theory of entering and being in autorotation is not necessarily lacking, as most can accomplish that phase safely. It is the more advanced autorotation fundamentals that are being left out of most syllabi: teaching how to get to a spot by varying airspeed (and rotor RPM) while in autorotation. It is what transpires between the time of the engine failure and the point at which the pilot initiates the flare that can make all of the difference. Getting the collective down has been hammered into students' heads from the beginning, and it is obviously required and critical. However, getting the cyclic back immediately in some configurations is absolutely critical as well.

As a designated pilot examiner, it is common to see applicants struggle with hitting their spot. Why? My subjective opinion is that they are taught to enter the autorotation at a specified location in order to hit that spot. They enter the autorotation, realize they are short or long, and then the specified airspeed and rotor RPM they were taught is either getting critically low, or astonishingly too high. Who is to blame: the student, the instructor, or the system? After all, it is the PTS that dictates that an applicant will "establish proper aircraft trim and autorotation airspeed, ±5 or ±10 knots."

I am absolutely amazed to see students, pilots, and instructors alike think something bad is going to happen if their airspeed drops below the recommended autorotation airspeed during the initial entry or at some point below the HHP and/or above the "knee." Where does this mindset come from? Obviously it comes from the PTS that dictates that an applicant will maintain best autorotation speed within the given tolerance. This is rather unfortunate considering airspeed indicators are typically not reliable in autorotation. In an engine failure or a practice autorotation approach from cruising level altitude (at or above the HHP on the H/V curve), all I care about is: (1) getting upward airflow through the rotor disc to serve as the driving force, and (2) making sure my RRPM is where it needs to be.

Initially, I don't care about airspeed. Airspeed becomes critical prior to the initiation of the flare for one solid cardinal principle: There is an airspeed below which the flare will be spectacularly non-effective. I am *not* suggesting that one become a weekend warrior test pilot. Do not go experimenting to find the lowest airspeed you need at the flare initiation; just know that you will need a practical amount of airspeed, and this is something that can be learned with the proper instructor. Also keep in mind the design factor(s) of a helicopter; unlike a fixed-wing aircraft, helicopters are designed to land vertically with little forward horizontal momentum.

Regarding hovering, I am also absolutely amazed to see pilots hovering at heights greater than the *LHP* in light training helicopters. If the engine fails above this point, there is a real risk of damage to the airframe … as well as good potential for a bad back!

Summary

Knowing and being able to maneuver in and out of the H/V curve is important. Knowing how the H/V diagram is developed, and that it is based on minimal (normal) pilot skill and under not-so-ideal conditions, should bring new light to how you approach autorotations—simulated or real. Train like you fly, and fly like you train … and strive to be better than the normal skill level.

For those who want to learn all they can about autorotations, here are very important resources:

The Little Book of Autorotations written by my friend and mentor Shawn Coyle, retired flight-test engineer and author of the highly acclaimed book *Cyclic & Collective*. This autorotation book may have "little" in the title, but it covers nearly everything imaginable on autorotations, from in-depth certification factors to who should actually be teaching autorotations. The book is available as an e-book via Kindle.

Additionally, for those who thirst for more knowledge on this subject, Pete Gillies of Western Helicopters is a true professional and educator and an absolute must-fly-with instructor when it comes to learning the ins and outs of autorotative approaches. It is Pete who has mastered the "get the cyclic back" philosophy that we so desperately need in our industry.

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