The Geometry Of Visibility

Do as much prior planning as possbile to avoid getting caught too high, too close in.

By Wally Roberts

THE INSTRUMENT RATING GIVES us the freedom and flexibility to fly without reference to the natural horizon or other visual points of reference. It's possible to takeoff and see nothing but clag out the window for hours until shortly before landing at your destination.

Except for the elite "CAT III autoland club," something meaningful must be seen at the appropriate position before you can descend below the minimum instrument altitude and visually position the aircraft for a safe landing. This is so obvious it hardly seems worth stating.

Sometimes, however, it's those obvious things that reach out and bite us really hard when the weather is really in the pits. When we practice approaches in the aircraft, we're usually under the hood, and the visibility is always well above minimums. Then, our friendly neighborhood CFII pops the hood and proclaims, "Runway in sight!" Even when we're fortunate enough to practice during actual conditions, the visibility is usually better than minimums.

I've written about the various aspects of instrument approach visibility[1] more than any other component of the TERPs equation. Previous articles have considered the regulatory and operational aspects of required visual references, both with prevailing visibility and with runway visual range (RVR), and also with and without approach light systems. This article will dwell on the geometric relationship of visibility vs. the height above touchdown (HAT) of the MDA.

Normal final descent

The most critical segment of the final approach for landing usually begins at 500 feet HAT and continues to flare and touchdown. This is especially true for jet transport aircraft that can tolerate very little deviation from optimal stabilized flight for this last portion of the final approach. But even more maneuverable, smaller aircraft need a stable final approach to flare and touchdown during the often short visual segment of an IAP when the visibility is poor.

It's generally accepted that a three-degree approach angle is optimal for all jet aircraft, from the small bizjets to the really big birds. This is the angle that's neither too shallow nor too steep. Too shallow means the airplane "drags in" with too much power and too steep a cockpit deck angle.

The shallow approach decreases clearance from the ground or other obstacles and, at the same time, the view of the runway from the cockpit is shortened and distorted. Too steep an approach is okay from an obstacle clearance standpoint, but flare management becomes more difficult with the possible result of either a hard landing or an excessive float.

Smaller, straight-wing aircraft have a wider range of acceptable final approach angles. Nonetheless, there are reasonable limits. No airplane should be flown at a final approach angle of less than 2.5 degrees. The upper limit for small aircraft is approximately five degrees, provided a rate of descent of less than 1,000 feet per minute is achieved during the last 500 feet of altitude. Five degrees is the upper limit with the limited visual conditions often present during IFR weather, where visual perception is limited and the objective is to make a safe touchdown in the acceptable touchdown zone.[2]

"Precision" in precision IAPs

Because a single instrument approach procedure must serve all types of airplanes expected to use the approach, the precision IAP is driven to accommodate the most critical case: the large jet transport airplane. As a result, most ILS glideslope angles are set at 3.0 degrees unless final segment obstacles require a steeper angle.

Table 6. EFFECT OF HAT/HAA ON VISIBILITY MINIMUMS

HAT/HAA (ft.)	250-320	321-390	391-460	461-530	531-600	601-670	671-740	741-810	811-880	881-950	951 & above
CAT A	1mi------									1¼------	
CAT B	1mi------							1¼------			1½
HAT/HAA	250-400		401-500	501-600		do	do	do	do	do	do
CAT C	1 mi		1¼	1½		1¾	2	2¼	2½	2¾	3
HAT/HAA	250-341	342-426	427-511	512-600		do	do	do	do	do	do
CAT D	1 mi	1¼	1½	1¾		2	2¼	2½	2¾	3------	
HAT/HAA	250-320	321-390	391-460	461-530	531-600	do	do	do	do	do	do
CAT E	1 mi	1¼	1½	1¾	2	2¼	2½	2¾	3------		

TERPS Table 6. Effect of HAT/HAA on Visibility Minimums*. The highest visibility for Category A is 1-1/4 miles for HAT/HAA above 880 feet; for Category B, the highest visibility is 1-1/2 above 950 feet; for Category C, the highest vis is 3 miles above 950 feet; and Category D is 3 miles above 810 feet.*

The ILS provides an electronic iron rail in the vertical profile. As a result, the pilot is spared the sometimes very complex task of assessing vertical position in relation to the runway, often with little time and with marginal visibility conditions. Further, many non-precision IAPs not only lack vertical guidance, they are so misaligned with the runway that the pilot is faced with the additional task of aligning the airplane with the runway while attempting to get into the correct vertical profile on short final.

Not only does the ILS provide a rock-solid vertical path that assures precise vertical positioning for landing, the DH concept places the missed approach point at the optimal position. Either you have the required visual reference when in the landing slot or you pull up before getting too-high, too-close-in. That's what a precision approach is all about.

Politics of minimums

Before the United States converted to the TERPs operating concepts in 1967, both ceiling and visibility were required to begin an IAP. The TERPs concept eliminated any consideration of ceiling, other than to not descend below MDA (or continue descent below DH) unless adequate visual cues are present.

There was a rash of jet transport crashes during non-precision IAPs in the early days of TERPs. The required visibility minimums didn't bear any rational relationship to the vertical difference between MDA and the runway. In the mid-1970s, the FAA decided to tighten down the requirements for the airline jets, i.e., Approach Categories C and D.

TERPs Table 6 (page 10) is the primary basis for visibility minimums. These values can be reduced by up to one half mile if the runway has an approach light system and the critical last 10,000 feet of the final segment is relatively obstacle free below MDA or DH.

Category A aircraft are allowed one-mile visibility through an HAT of 880, then it becomes 1-1/4 mile regardless of the HAT. Category B is almost as permissive: it allows one-mile visibility to an HAT of 740, 1-1/4 mile to 950, where it becomes 1-1/2 regardless of HAT.

The Category A descent angle from 880 feet at one mile is 9.6 degrees. The Category B angle from 950 feet is 8.3 degrees. These approach angles are too steep for most light aircraft to make a safe visual final approach below MDA during limited visibility conditions. Add nighttime and/or rain or snow, and it becomes an even bigger problem.

Of course, the visibility is seldom at minimums, especially around the one-mile range. More often than not, the visibility is either quite a bit better or worse than one mile.

The descent angles for Category C aircraft range from slightly less

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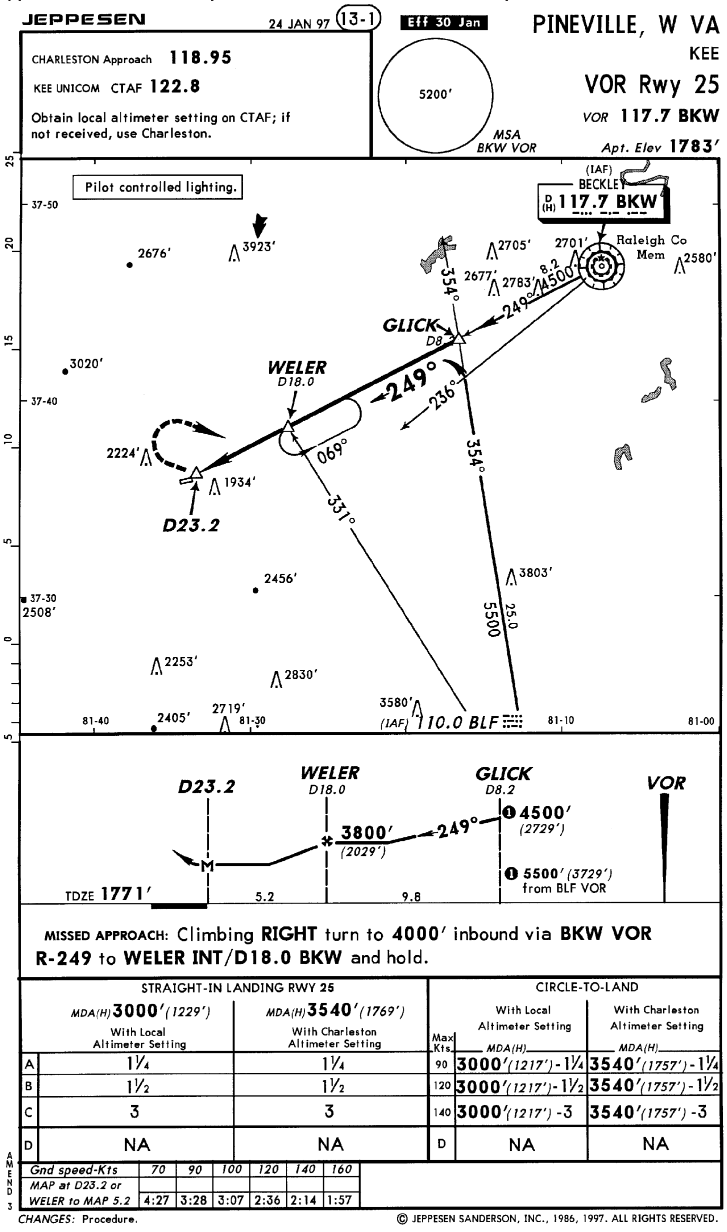

With the local altimeter setting HAT of 1,229 feet, the descent angle from MDA to the runway is 10.7 degrees at 1-1/4 miles visibility and 8.9 degrees at 1-1/2 miles vis.

The Geometry…

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than 3.0 degrees to slightly more than 4.0 degrees, and stays well below 4.0 degrees for Category D. These two higher categories don't permit very high HATs until the basic VFR visibility of three miles is achieved.

Real world case-study

Refer to the VOR Runway 25 IAP at Pineville, WV (page 11). This is a great case study, which contains several problems that exacerbate non-precision IAP problems at many small airports. The HAT of the straight-in MDA is quite high (1,229 feet). The HAT becomes significantly higher when the CRW remote altimeter setting must be used (1,769 feet). The MAP is 23.2 miles from the VOR station, which results in a sloppy final approach course near the airport.

Note the HAT of the MDA is sufficiently high to trigger the 1-1/4 visibility requirement for Category A, the 1-1/2 mile requirement for Category B, and the three-mile VFR requirement for Category C. With three miles visibility, the small bizjet would probably find the runway in time for a safe, final visual descent to landing. But, what about Categories A and B if the visibility is actually at minimums?

Let's assume the actual visibility is at minimums, and it exists uniformly through a homogeneous atmosphere to the base of clouds, which are slightly higher than MDA. With the local altimeter setting HAT of 1,229 feet when the pilot sights the runway threshold level at MDA, the required descent angle would be: (1) with 1-1/4 miles visibility—10.7 degrees; (2) with 1-1/2 miles visibility—8.9 degrees.

Note the remote altimeter setting (RAS) increases the MDA by a whopping 540 feet. Usually the RAS additive isn't this extreme. However, it brings out a significant point to consider: on one day the atmosphere might be sufficiently turbulent and unstable that an actual adverse pressure differential exists that places you at an HAT of 1,229 feet when flying at an indicated altitude of 3,540 feet. (That's the protection for which the RAS assumptions are providing.)

On another different unsettled day, however, you might be considerably higher than 3,540—safe from an obstacle clearance standpoint, but not so good from a visibility and MDA geometric standpoint.

When the atmosphere is relatively benign, the chances are the RAS will be close to what the local altimeter setting would have been, if it were available. Therefore, when flying the legally required MDA of 3,540 feet with the CRW altimeter setting, you're probably close to an actual HAT of 1,769. This increases the previously stated approach angles of 10.7 degrees (Cat A) and 8.9 (Cat B) to 15.6 degrees and 12.9 degrees, respectively.

How to descend safely

Obviously, in all cases of actual minimum weather conditions at this airport, it would be unsafe to descend straight-in for landing when first sighting the runway threshold. The only effective option is to circle to land on Runway 25.

At this airport, both the circling and straight-in MDAs are the same. In most cases, however, the circling MDA is higher, so you cannot be below the circling MDA when departing the electronic final approach course. Can you climb back to the circling MDA if you decide to do this? Yes, provided it's done prior to the MAP and prior to departing the electronic guidance.

Impromptu VDPs

It's also a good idea to have an impromptu visual descent point (VDP) pre-planned for any non-precision IAP with a high HAT. Be aware, though, a VDP is of little value when the visibility is at minimums for either Category A or B. This is because of the fundamental conflict in MDA/visibility geometry between the Table 6 limits and the angle required for a reasonable VDP. With Categories C and D, impromptu VDPs have a greater chance of working most of the time.

In our case study, I would have two VDPs pre-calculated using the BKW DME. I would first check to see whether the runway has a VASI or PAPI. If so, I would ensure my descent angle is at or above the visual indicator's slope. Because no angle is shown (below) for the AVASI on Runway 25, you can assume it's 3.0 degrees. I would pre-calculate a

ADDITIONAL RUNWAY INFORMATION

RWY		USABLE LENGTHS — LANDING BEYOND Threshold	Glide Slope	TAKE-OFF	WIDTH
7	❶MIRL				60'
25	❶MIRL ❶AVASI-L	3101'			

❶Activate on 122.8.

TAKE-OFF & IFR DEPARTURE PROCEDURE		FOR FILING AS ALTERNATE	
	All Rwys		
1 & 2 Eng / 3 & 4 Eng	800-1	A B C D	NA

IFR DEPARTURE PROCEDURE: Rwy 7, 25 climb on runway heading to 4000' before proceeding on course.

AMEND 0

Runway 25 has an abbreviated (A)VASI. Since no approach angle is indicated, you can assume it's 3.0 degrees.

three-degree VDP for the local altimeter setting and a four-degree VDP for the CRW altimeter setting. (The steeper angle would be a pad for being lower than the nominal HAT of 1,769.)

If you have a "trig" pocket calculator, you can improvise a precise VDP where DME is available. Otherwise, use 320 ft/ nm for 3.0 degrees, and 420 ft/nm for 4.0 degrees. Also, I like to have my informal approach angle cross the threshold (TCH) at 50 feet. (Note: these calculations should be made during preflight and not in the cockpit while getting bounced around.)

My precisely calculated VDPs for this approach are: 3.0 degrees for a HAT of 1,229: 19.5 DME; and for a 4.0-degree slope with a HAT of 1,769: 19.2 DME. If you simply use my "wag" numbers of 320 ft/nm (3.0 degrees) or 420 ft/nm (4.0 degrees) and disregard allowing for TCH, you will still be in the ballpark. If no DME is available, the result of your calculations should be a timing point for your impromptu VDP.

Caveats

Once you have your impromptu VDP available, and especially where you've proven its accuracy, you'll be tempted to depart MDA at this point when you can see straight down, but can't see one of the FAR-required visual cues. You must resist this temptation. Instead, the lack of required visual cues at your impromptu VDP tells you to press on toward the MAP at MDA, either for a circle-to-land or for a missed approach.

Keep in mind only FAA-charted VDPs assure obstacle clearance below the MDA. In the case of Pineville, the presence of the AVASI also tells us at least the last four miles of the final segment is free of obstacles below the VASI obstacle clearance plane. (The only reason Pineville doesn't have a DME VDP is because FAA policy prohibits charting of VDPs where there are two altimeter setting sources. This might change some day—stay tuned.)

Many non-precision IAPs not only have the vertical geometric challenges set forth in this article, they're also offset significantly from the extended runway centerline. The alignment maneuver to the runway becomes even more difficult on such IAPs when the visibility is low and the HAT of the MDA is high.

Wally Roberts is a retired airline captain, former chairman of the ALPA TERPs Committee, and an active CFII in San Clemente, CA. Visit Wally's web site at http://www.terps.com

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[1] IFRR June, 1995: "Establishing Visibility Minimums"; April, 1996: "What's Below MDA and DH?"; August, 1996: "Lights, Camera, Action!"; December, 1996: "Low Visibility Operations"

[2] For straight-in landing out of an instrument approach during limited visibility conditions the optimum touchdown zone is within the following general ranges: (1) small piston aircraft: between 250 and 1,000 feet beyond the approach end of the runway (AER), (2) large propeller aircraft and non-wide body jets: between 500-1,000 feet beyond the AER, and (3) wide body jets: between 1,000-1,500 feet beyond the AER. (Note that the upper limit of 1,000 feet for a small aircraft would be too generous for a very short runway. Also, the legally acceptable touchdown zone for commercial operations would be the first 3,000 feet where touchdown zone lighting is installed.)