SAFER LANDINGS THROUGH UNDERSTANDING VISUAL PATTERN ANGLES

by
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A recent accident survey by the SSA Safety Committee (Ref. 1) suggests that mismanagement of landing approaches by glider pilots may be causing an excessive proportion of glider accidents. A review of approach methods taught and used had already been under way seeking ways to upgrade this most important phase of every gliding flight. It resulted in the following discussion, which it is hoped may improve the general ability to control glider approaches. The concept should be useful to power pilots, especially when in a forced landing. The following discussion includes, advances, and concludes the work of Reference 3.

Shortcomings of the Altimeter as a Gauge for Approaches

The altimeter has, for many years, been taught as the most important single tool for judging glider landing approaches. Nevertheless, a characteristic comment from many instructors interviewed has been that "nobody" teaches the altimeter anymore for judging approaches (Ref. 4). Yet most instructors admit to establishing an "initial point" of a pattern by the altimeter. Two accidents already in early 1977 are attributed to erroneously set altimeters.

There is always a gray area delineating the difference between true landing patterns and traffic patterns which may confuse this concept of the use of the altimeter. Research by the author amongst pilots indicates that the altimeter is widely relied upon in pattern judgement during landing approaches by glider pilots and power pilots as well, and is so taught by many instructors. *The Joy of Soaring* (Ref. 2), part 1, section 7 shows the method of controlling glider landing approaches by matching various parts of a pattern to specified AGL altitudes. It is termed there a "traffic pattern" while treated more as an approach pattern. That treatise also recommends that approaches be taught with the altimeter covered, but how such a pattern is controlled is left as somewhat ethereal. Many instructors set the altimeter at zero on the field, and teach their students to do so. This practice would seem to give away the "secret" of actually relying on the altimeter for approach "control". Not only that, but it is contrary to FAR 91.81 (a) (i) (ii) (iii) and has been advised against by the Board of Directors of the SSA.

But we hasten to emphasize that we are not telling how to instruct in this discussion, and the foregoing is primarily for background. Let us consider the shortcomings of the altimeter for judging glider approach patterns, these deficiencies being well known and can be cumulative:

1) The altimeter may not have been set for the barometric pressure at the time of the flight.

2) The barometric pressure can change significantly between the beginning and end of a long flight.

3) The pilot may have made the easy mistake of setting the altimeter 1000 feet wrong, either too high or too low, when setting to ground elevation (according to the above FAR).

4) When landing off airports, the ground elevation may not be known, in which case the altimeter could not be relied upon to determine the height above the terrain. (This would be a problem in forced landings due to engine failure in power planes, also).

5) The altimeter barometer scale may be out of adjustment.

6) The AGL altitude may be as "scheduled" but the pattern may be flown too wide from the landing place putting the glider in a dangerously "low" approach position, or it may be too close, causing the pilot to lose sight of the area he desires to land in, as well as to cause him to overshoot.

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7) A pilot, relying on an altimeter, may get in trouble as a result of a delay or diversion from the planned approach, if it puts him out of position for some type of standard approach he has been used to making, which is altimeter controlled. He might not be capable of judging it some other way.

Such "derailment" of approach patterns is a very real possibility. Other traffic may get in the way. The landing area may be suddenly blocked by people, equipment or animals, as happened tragically, in the International Championships in Yugoslavia several years ago, when the pilot hit a truck that crossed the farm field he was landing in and he was killed. Some accidents come *after* avoiding a wire or tree that the pilot had not seen until the last minute (Ref. 10). Something can go wrong in the glider, as when the author was landing in a populated golf course, but the parachute pack had slid behind his arm preventing him from getting the flap into the steep approach position. The chute had to be moved, and the approach revised, with time running out.

Of course, in powered airplanes, provided the engine is running, the pilot can use his throttle to give himself another chance, but in a glider or power plane with engine out, the approach must be carried to a conclusion even though that conclusion is a crash.

Controlling the Landing Approach Pattern by Viewed Angle

Regardless of which of the many methods we prefer and use to manage and teach glider landing approaches (as well as powered plane forced landings), the vertical angle at which the pilot *looks down* on the area he plans to land in is a potent indicator of his position. He sees the runway at some angle below the horizon when he first glimpses it from afar coming in from a flight, and he judges his approach position by the changing angle during the entire circuit of the pattern whatever that may be. This use of the angle the field is seen below the horizontal for approach control is not a new idea. Pilots have been judging approaches this way since flying began, and its use has been classically referred to as "feel" or "sense". A clear understanding of this viewed angle and what it means to a pilot, is our major concern in this discussion.

The idea has been touched on in recent power pilot's manuals, specifically those offered to prepare for the biennial flight review. But the treatment of the subject has been indefinite and qualitative. While "gun-sighting" the final glide by reference to a mark on the windshield and a point on the landing area is well known (it was used to train army pilots in helicopters in the 1950's), treatment of the view of the runway from the side of the cockpit is what we refer to as obscure.

During the following discussion of the so-called "French" pattern, we are not advocating that pattern in particular in preference to any other (though the author likes it). Rather we use it as an example, for they have been successfully teaching approach judgement by it for some years.

The "French" pattern was introduced to the author during a discussion of approaches by viewed angle with Sam Harmatuck, a retired communications engineer of the City of New York. Sam is an instructor in the McASA Glider Club flying out of Wurtsboro, New York. He had flown at a glider site in France where the pattern was taught by this method, and he described it generally as follows:

The glider entered the pattern somewhere in the downwind leg at an angle "above the runway" as he put it, of 26 degrees. This establishes a height AGL equal to one half the distance out from the runway. (The angle whose tan is 0.5 is 26.56 degrees and it would be fruitless to try to judge the angle within five or ten percent). The downwind leg was flown in that position. Obviously the glider must have entered the pattern not too low AGL. Pilots trying the 26 degree position for the first time will find themselves in a pattern that may well be higher than they are used to. A further feature of the "French" pattern is how they teach the turn into the base leg. They establish this as the point, after the glider has passed the end of the runway downwind and reached an imaginary line lying on the ground 45 degrees from the runway centerline. See Figure 3. At entry into base the French teach application of full spoilers, which are held full throughout the base and final legs. The author observes that while holding spoilers fixed and full on may be good training in precision flying, it is obvious that the usual means also are available to adjust for wind or for errors of position that might be taking the flight into an under or overshoot situation. The pilot can broaden or tighten the base leg, he can retract spoilers partially or entirely, he can slip with spoilers full on, and he can turn sooner or later than the 45 degree "lay" position. Even the 26 degrees viewed angle is not sacred, once the pilot has learned satisfactory judgment by the method. There are many approach variations that are characteristic to different clubs, schools, or individuals. But it is clearly better never to allow oneself to delay correcting an undershoot position, since there is no fix for that once the glider has gotten too low. To correct for overshooting, slipping with spoilers full on should be fully mastered with the glider you are flying, though with the very effective dive brakes such as Schreder flaps, slipping would seldom seem a requirement.

Rudiments of the Viewed Angle Approach

What is this viewed angle we have been discussing? While we have said that the "French" pattern places the glider in the downwind leg 26 degrees "above" the runway, there is really no way a pilot can make a mental measurement of this angle his sightline makes with the ground. And if he could do that, sloping terrain in the vicinity of the runway, or of an area he is landing in off airport might seriously confuse his judgment. However, there is another angle which, by geometry, has the same value as the angle "above" the (level) field. This is the angle formed by the pilot's line of sight to the field combined with that to the horizon (which is the same as along the horizontal.) Seeking a simple name for this angle of view below the *horizontal*, we have borrowed from the surveyor, and call it the "dip" angle. Quotes are used here to distinguish our use of "dip" from that of the surveyor, which is the angle a magnetic needle swings below the horizontal. See Figure 1.

How We Judge By "Dip" Angle

The important thing to understand about this "dip" angle is that the pilot sees it *from its point or vertex*. It is a little like looking up a narrow fork between two roads while standing at the intersection, then turning the land on edge. The importance of this "dip" angle cannot be overstated, and we shall elaborate upon it.

At pattern altitude, the pilot's sightline to the horizon is within one degree of truly horizontal.[1] What the pilot actually

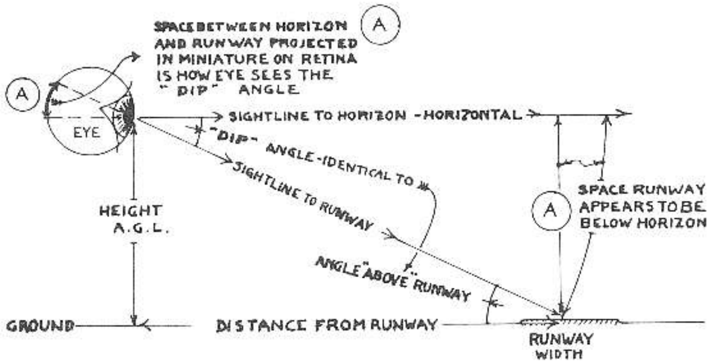


FIG. 1

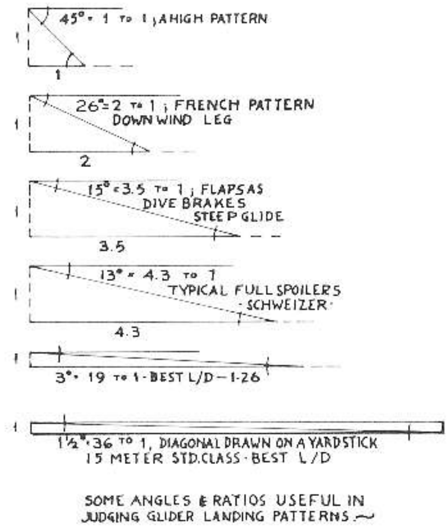


FIG. 2

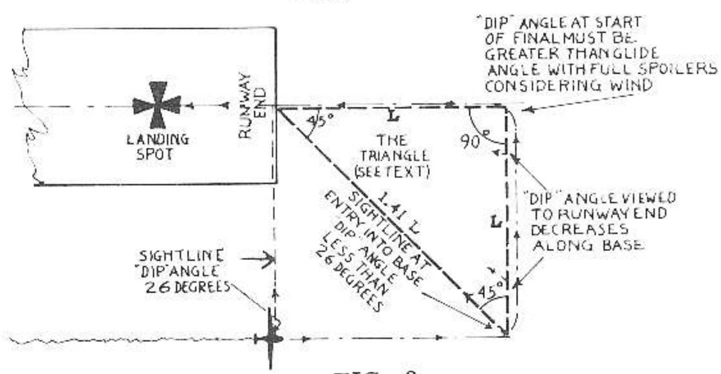
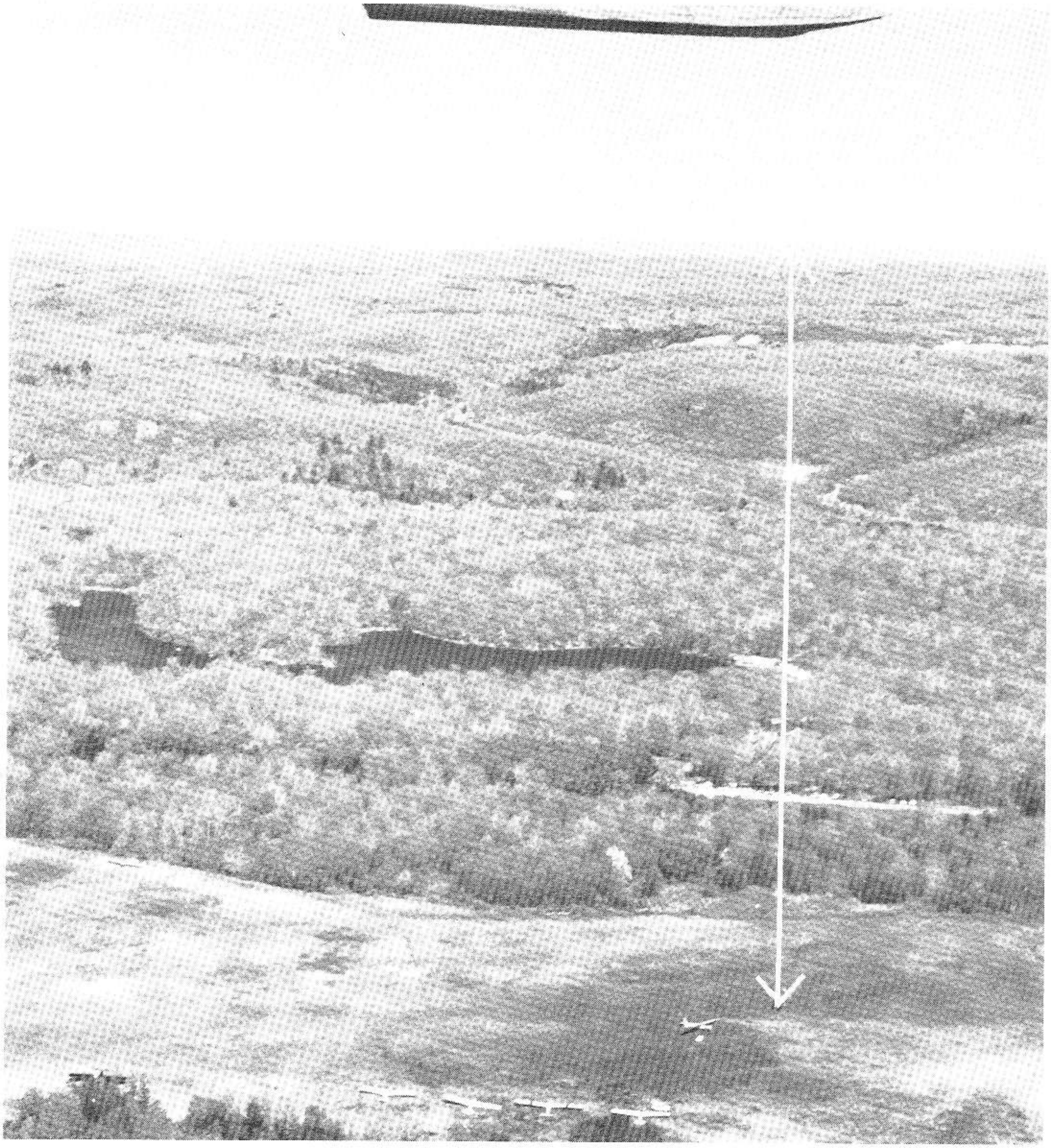


FIG. 3

sees when he views the runway below the horizon is a *space* between the horizon and the runway. The view of this space is how the "dip" angle is projected upon the retina of the eye. (Ref. 7) The eye can perceive dimensions only angularly, never linearly. The tiny image of this space could be measured if we could get inside the eye to do it. See Figure 1. By elementary geometry its measurement will always be the same for any angle,

[1] The "dip" angle of the horizon seen from 1/4 mile AGL (1320 ft), the radius of the earth taken as 4000 miles, calculates to be 0.75 degrees.



To view the photograph, look at it from a distance so the eyes are twice as far from the page as the length of the arrow. This makes the arrow look the proper length for a 26 degree "dip" angle, as seen from the glider. Because of the small format, some readers will not be able to see the photo clearly viewing it so close.

say A, and for any angle other than A it will be a different size. It doesn't matter if this viewed angle is that subtended by this page held before your eyes, or of the world outside the glider. If the viewed *space* subtends a 25 degree angle at the eye, it will always be projected the same *size* on the retina. A 12.5 degree angle would project a space on the retina of half the size, and a 50 degree angle, twice the size for a 25 degree angle. And the important thing about this is what we can *memorize* the size of the space for a given angle! We will discuss more of this below but for the moment, let us consider the judgement of altitude by eye alone, should the altimeter seem to be wrong.

Limitations of Binocular Vision For Judging Altitude

Large distances are not judged stereoscopically at all. The eyes are less than 3 inches apart, and this spacing is the base for the binocular judgment of distance. At distances that are large multiples of the spacing of the eyes, binocular vision becomes useless for our purpose. Five hundred feet is more than 2000 times the spacing of the eyes and beyond that, the binocular feature has ceased to be a reliable measuring method. Pilots do learn to judge these large distances pretty successfully provided they are in familiar surroundings. This is done not by binocular vision but by comparison of the *angular* size the object is seen. This function is similar to seeing the "dip" angle we have already discussed. If the familiar object is twice as far away as a like object, it looks half as large - half as far, twice as large. It is noted but believed not very important that upon removing one's glasses, the size of the viewed object seems to change. Refer to Fig. 1.

When the Horizon is Obscured

Going back to the viewed angle of the airport as seen below the horizon, what we called the "dip" angle, the pilot does not measure this angle in the *eye*. The measurement and comparisons are made from the visual inputs after they have reached the *brain*. These outside sights are being flashed intermittently and very rapidly into the brain. This goes on while the head is swiveling (Ref. 5) and the eyes are flashing glances in every direction. From this input, combined with certain senses from the inner ear, the brain establishes a reference, a concept of the surrounding environment. The horizontal is predominant in this reference and is held still, as it were, in the brain - in the memory, until it is upgraded by sequential visual inputs. The brain's concept of the horizontal has to be continually updated as the aircraft moves about and across the terrain. *And there does not have to be a visible horizon to do this.* Experienced pilots know that they can fly even though the horizon is completely obscured so long as they have occasional views of the terrain below. If the terrain is lost from view, then it is only a moment before the pilot becomes disoriented, and must fall back upon his instruments for guidance. (Note that the National Transportation Safety Board warns of spatial disorientation as a major cause of fatal accidents with pilots who are not instrument trained. It occurs when ground and horizon are obscured, or the horizon is severely obscurred.)

Because the measurement is made in the brain, not in the eye, it is possible for the pilot to determine the "dip" angle of the viewed landing area *even though he cannot see the horizon.*

This is the true explanation of how pilots judge approach patterns, how they just seem to *know* if the approach is "off" or "right on". It is how a pilot can *sense* when the altimeter is not telling him the truth. It is the thing we have heard called "sense" and "feel" in the judgement of patterns. This is not some mysterious psychic thing that cannot be clearly explained. It is simply the making of mental comparisons with familiar viewed angles that the pilot has already learned. It is a thing he has been doing since he first began to walk, and has refined as he went on to bicycling, playing ball, driving and ultimately to flying.

We shall admit that the 26 degree angle, or any viewed "dip" angle cannot be judged perfectly, but it *can* be judged. Furthermore, it is something that is at the pilot's call whenever he needs it provided he is properly skilled in its use. This puts it not only way ahead of an altimeter that is giving him wrong information for judging approaches, but it is superior to something he has been told is "sense" or "feel" but that he does not understand. And understanding the angle is the important thing.

Turning into Base and the Viewed Angles

There are many ways of teaching students when to turn into the base leg from the downwind leg and we do not advocate the angle of view as the only method, even though it is certainly a reliable check when other methods seem out of kilter. Instruction methods in schools are established though, and we are not trying to change them. But the turn into base can also be controlled as in the "French" method by a viewed angle, call it the "lay" angle, lying flat on the ground. Nevertheless, it may be easier to say to the student something like: "turn into base when the end of the runway is half way to the tail," or "...when you are opposite the end of the field," than to try to explain and to teach the 45 degree or some other turn-in angle on the ground. But use of the "dip" angle is still a very reliable way to guard against being too "low" or too "high" when the turn into base is made. The idea is also adaptable to other approaches than the rectangular, such as the spiral, oval, or circular, or even straight in. Such approach patterns will be familiar to pilots landing out, and finishing long contest final glides, as well as after passing through contest finish gates and making the go-around to land, often in the face of other contest finishers.

Teaching and Learning the Viewed Angle

The question has been asked whether the viewed angle is not as difficult to judge as is an altitude (Ref. 4). Where the terrain of the landing place is unfamiliar and that area has no particular delineation of its borders, then to judge altitude visually even by comparison with familiar objects, (which aren't there) becomes ineffective. New England pilots flying for the first time in Texas or New Mexico will experience this problem and seaplane pilots are well aware of it. We have already shown how binocular vision has its limitations. But the viewed "dip" angle of stones or vegetation on or near the landing area is still useable. And it provides a safer way to judge the pattern than by attempts at visual estimates of altitude.

The viewed angle, to be used, however, must be taught and learned somehow. This is ordinarily done unconsciously and automatically without the student, or indeed the instructor, being aware of how. It happens while the student is being shown and is practicing patterns in his early training. But it actually is possible to demonstrate the viewed angle in ground school, and it is easy to do. It can be learned there as a specific quantitative thing. Doing this helps the student to understand the concept and offers the matured pilot a way of self-teaching, and of refreshing his memory after a layoff from flying.

Here is how it is done. Draw a chalk line on a wall at eye level and then step back a distance equal to twice its height from the floor. You will now see the floor junction with the wall at a 26 degree angle below the chalk "horizon." If you do this several times, preferably with a time lapse in between, you will find that you can walk up to a wall without the chalked horizon and stop at just about the right place for the "dip" angle to be 26 degrees. This is analogous to how, as we approach the pattern from afar, we see the runway below a visible horizon, as its "dip" angle is approaching the desired 26 degrees. The "dip" angle will be less from afar, and increases as we approach the pattern. It will begin to decrease again in the base leg. An excellent in-flight teaching tool is a 5 x 7 inch card with the dip angles of interest drawn on it from a corner and an edge. The edge of this card is sighted from the cockpit to the horizon, and the runway "brought in" to sight down the line. The card is discarded as soon as the student has the idea. Or it may be carried for future reference.

We have figured the "dip" angle from 5 nautical miles out, to reach a 1000 foot pattern, in a 1-26 flying at 56 knots against a 28 knot (half the glide speed) headwind. (Ref. 6) It would be about 10 degrees. This will be a pretty high glide if the air is unstable, and the glider may well arrive with altitude to spare over the 1000 foot pattern. If the pilot enters the pattern too high, he will merely fly a "bigger" pattern by angular references, and will nevertheless come out at his chosen landing spot. If he is coming towards the pattern too low, he will be alerted early by the viewed angle in time to take careful action, whatever it is.

When to Use the "Dip" Angle in Landing Approaches

As has been said, we are not proposing that instructors stop teaching whatever they are teaching today and start telling students that the angle of view is the only way to judge approaches, even though we think it may very well be. For one thing, this would be unsafe from the standpoint of the *traffic* pattern at busy fields, and it might also be controversial with some instructors or clash with an established curriculum. What we do propose is that the viewed angle method be *explained*, and *understood* and *practiced* enough so the student can make use of it for judging approaches. Conscious use of the idea can only upgrade the precision of landing patterns, of whatever type, thus reducing accidents caused by bad approaches. It will be a great comfort when the altimeter "looks funny" or the approach has been upset to know that you have a reliable alternative for carrying through the landing safely.

How the "Dip" Angle Changes During the Base and Final Legs

At the start of the base leg in the "French" downwind position, the pilot (Fig. 3) sees the end of the runway at nearly the 26 degree "dip" angle. As he flies along the base leg in still air, assuming a rectangular pattern, the "dip" angle must not become less than the glide angle of the sailplane, taking into account the effect of spoilers and of the wind. The glide angle with spoilers extended, from table 1, is typically 12 to 13 degrees; no wind, and many sailplanes have more effective dive brakes than do those in the table. This is approximately half the "French" downwind leg "dip" angle of 26 degrees. With the headwind of one-half the glide speed or a component of it in the final glide, a situation that doubles the glide angle, the pilot would be too low starting the final glide at a "dip" angle of 13 degrees, if he were to hold spoilers full on. He should correct for this undershooting situation promptly by one of the already-discussed methods. Obviously, if he had started the base leg at 26 degrees "dip" angle (see Fig. 3), it would not have stayed at that value, but would have decreased due to losing altitude in the base, a thing the pilot intends to do. Retracting spoilers to flatten the glide angle would be the key to the above undershooting situation. But, if the spoilers were not already out, it is obvious that they could not be retracted.

REFERENCES

1. Stephen du Pont, "An Analysis of Gliding Accidents" (From FAA reports) *Soaring*, January, 1977.

2. Carle Conway, *The Joy of Soaring*, SSA, 1969.

3. Stephen du Pont, "An Optional Way of Judging Glider Approaches," read before the SSA Reg. 3 Safety Symposium, November, 1977, Elmira, N.Y.

4. "An Optional Way of Judging Glider Approaches," *Soaring*, February, 1977. (Abridged and revised by editors of *Soaring* from Reference 3 above.)

5. E. Bizzi, "Coordination of Eye Movements," *Scientific American*, October 1974.

6. S. du Pont, *New Soaring by the Numbers*, Stephen du Pont, 1974.

TABLE 1
From Reference 8

SOME TYPICAL GLIDER GLIDE RATIOS, DIVE BRAKES OUT

TYPE	DIVE BRAKE POSITION	WEIGHT	SPEED KTS	SPEED MPH	SINK FT/MIN	GLIDE RATIO TO ONE	APPROX. DEGREES
2-33	Full	Solo	48	55	750	5.62	10
2-33	Full	Solo	52	60	1050	4.95	11
2-33	Full	Dual	48	55	775	6.17	9
2-33	Full	Dual	52	60	950	5.49	10
1-26E	Full		48	55	800	6.05	10
1-26E	Full		52	60	1100	4.80	12
1-34	Full		48	55	850	5.62	10
1-34	Full		52	60	1075	4.90	11
1-35	Full	No water	48	55	1050	4.60	12
1-35	Full	No water	52	60	1400	3.77	15
1-35	Full	Full water	57	65	1250	3.82	15
1-35	Full	Full water	60	70	1475	4.12	14
HP-18	65 deg.	No water	65	75	1700	3.82	15

7. Scientific Encyclopedia, "Eye," Van Nostrand, 1938.

8. B. Carris, "Glide Test Reports," Schweizer Aircraft Corp., 1976.

9. R. Johnson, *American Soaring Handbook*, Chapter 6, SSA.

10. FAA Preliminary Accident Reports, 1974 through 1977.

APPENDIX

Evaluation of the French Pattern by an Imaginary Flight

It seems interesting to evaluate the "French" numbers for the viewed angles including the turn-in-to-base angle, to see how they would actually work out. Since this portion of the discussion is somewhat technical, it is put in an appendix where it may be disregarded at the option of the reader. (It is noted that these numbers are not appropriate for power plane forced landings.)

Let us make a "flight" through the base leg and the final glide starting from the downwind leg, at the 45 degree "lay" position and the "dip" angle of 26 degrees. Our imaginary path is somewhat hypothetical. Looking down from above, Figure 3, the base and final legs form two equal sides of a right triangle. These sides are equal because of the 45 degree angle, by elementary geometry. The line of sight from the start of the base leg to the end of the runway is the hypotenuse of the right triangle. Call the length of the base and final legs each "L". Solving by the Pythagorean theorem the sightline is 1.41 L, and the two legs add up to 2 L. For simplicity, disregard the slant of the right triangle. Now for a moment consider a flight along the sloping slightline (the hypotenuse) with full spoilers. The glider would not glide as steeply as the 26 degree "dip" angle, because its glide angle from Table 1 is 12 degrees, spoilers full-out. This is half the sightline "dip" angle, so the glider would go twice as far as the length of the sightline. This would be 2.82 L. Now go back to the distance it must go to get to the runway, around the two legs, which is 2 L and we see that it can reach the runway end and have .82 L to spare (2.82-2=.82). We have shown that the pattern is o.k. so far. This is with no wind and with full spoilers applied.

Now consider a headwind, in the final glide, of half the glide speed. Such a headwind halves the ground speed and ground distance covered in a given loss of height, requiring the glider to go twice as far as in still air, (2L). We can figure the crosswind leg with a navigational computer (E6B etc.) finding that it requires flying 1.16 times as far as in still air. So 2 L + 1.16 L = 3.16L is how far we must fly through the moving air, and from the above we see that we are only able to fly 2.82 L. Subtracting we find that we would undershoot by .34 L. We have already discussed means of compensating for such an undershoot, one of which is to retract spoilers. In a headwind for best glide ratio over the ground, a good rule is to add half the wind speed to the best glide speed for still air (Ref. 9), p. 21, 22 and (Ref. 6), p. 25 and fly at that speed. If we do these things soon enough, we will certainly make the runway, and the "French" pattern would work out o.k.

NOTES

1) Feedback received from glider instructors about the previously published paper suggests that *ratio* is more meaningful than *degrees* to glider pilots in numerically describing the so called "dip" angle. Glider pilots are already familiar with ratio in describing L/D glide ratios, which is quite analogous. Refer to Figure 2 in the paper.

2) Further experiment in terrain where the horizon is not visible due to being obscured by mountains suggests that pilots may, probably do, refer viewing angles (in the vertical plane) to the directly sensed "plumb line" vertical instead of to the "conceptual" horizontal, which has to be mentally derived from it.

Such an angle would be sensed upwards from this vertical rather than downwards from the horizontal. The same numerical ratios could apply (see Note 1) though they would be the tangent of the compliment of the so called "dip" angle. We have said that this is only possible in straightline unaccelerated flight, and requires constant visual terrain reference. Refer to Figure 1. The foregoing is probably done quite unconsciously. It is difficult to escape from the habit of thinking of the horizontal, the horizon, as the most basic spatial reference in aviation.