Highlights and Margin Notes in
Wolfgang Langewieshe's

Stick and Rudder: An Explanation of the Art of Flying

Perhaps my notes and observations will inspire you to buy your own copy and learn from this classic…or to take the copy you already own off the shelf and revisit its great lessons, just as I am doing again now.

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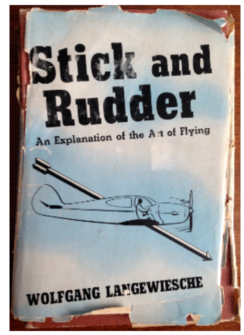
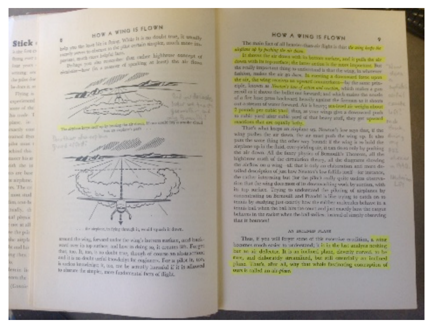
I earned my Private Pilot certificate in May 1985, shortly after purchasing a 1946 Cessna 120 that I used to build most of my experience toward my Commercial certificate. After separating from the U.S. Air Force I went to a local FBO in Boonville, Missouri part-time for about a month and earned my Instrument rating, my Commercial and my Flight Instructor certificate. About that same time I happened across a beat-up first edition/ninth printing (1944) copy of Wolfgang Langewiesche's *Stick and Rudder: An Explanation of the Art of Flying* at a yard sale for 20 cents. I bought it, took it home, and devoured its wisdom.

See:
https://en.wikipedia.org/wiki/Wolfgang_Langewiesche
https://www.amazon.com/Stick-Rudder-Explanation-Art-Flying/dp/0070362408



My marked-up and well-read copy of Stick and Rudder

Further back, an essay that has had a life-long influence on me is Dr. Mortimer Adler's "How to Mark a Book," (thank you, Mrs. Mak and your Junior English class at Kailua High School 1977-78) . Like *Stick and Rudder*, Adler's famous essay was also written in the early 1940s. So when I discovered *Stick and Rudder* quite accidentally in 1988, just five years out of college myself, I applied Adler's advice and marked the heck out of the flying techniques book—yellow-lining key points and making annotations in the margins not only to highlight what Langewiesche said, but also *what I was thinking* as I read his words.



See http://chuma.cas.usf.edu/~pinsky/mark_a_book.htm

My marked-up, well-read copy of *Stick and Rudder* has been sitting un-reviewed for many years on my home office bookshelf. I committed to re-reading and renewing this great book to review the author's wisdom, but also to see if there's anything I'd add—*or anything I've forgotten*—in my highlights and margin notes.

So, here are my notes on Wolfgang Langewiesche's essential classic: ***Stick and Rudder***:

Part I: WINGS

Chapter 1: "How a Wing is Flown"

Page No.	Highlighted Text (Langewiesche's words)	My margin notes
3	Flying *is* difficult to learn.	
	The flier' instincts—that is, his most deeply established habits of mind and body—will tempt him to do exactly the wrong thing.	
	There are situations in flying when he who "ducks," he who flinches, is lost.	Pilot must know what to do, and do it, without thinking.
4	The pilot must learn not to give in to his instinct of self-preservation, but to substitute for it carefully trained	"carefully trained reactions"

	reactions.	
	Our common sense, our natural reactions mislead us simply because they are working on the basis of wrong ideas in our minds concerning the wing and how it really flies, the controls and what they really do.	Yoda: "You must unlearn what you have learned."
	If we could only understand the wing clearly enough, see its working vividly enough, it would no longer seem to behave contrary to common sense; we should then expect it to behave as it does behave. We could then simply follow our impulses and "instincts".	Must develop "air sense"
5	"Theory of Flight" usually becomes a theory of building the airplane rather than of flying it. It goes deeply—much too deeply for a pilot's needs—into problems of aerodynamics. But it neglects those phases of flight that interest the pilot most. If often fails to show the pilot the most important fact in the art of piloting—the Angle of Attack, and how it changes in flight.	
	This whole book [is] and attempt to refocus "Theory of Flight."	
6	Angle of Attack is in a way *the* theory of flight. It is almost literally all there is to flight.	Knowing AoA does not make you a skilled pilot, but you can't be a skilled pilot without understanding AoA.
	No maneuver can be fully understood unless you understand this one thing.	
	You will be able to analyze your own mistakes.	
	Angle of Attack has no similes in our life on the ground.	
7	In most airplanes the angle of incidence is negligibly small—one or two degrees or even zero. Angle of incidence will generally be disregarded; it will be assumed that the airplane is built with zero angle of incidence.	
	Angle of Attack is the angle at which the wing meets the air.	AoA is the difference between the direction the airplane is pointed and the direction it is going.
	In British usage, angle of incidence means what Angle of Attack means in American usage.	
	Forget Bernoulli's Theorem.	
8	The airplane keeps itself up by beating the air down.	And yet decades later we still teach Bernoulli, and only Bernoulli.
		Does that also explain ground effect?
9	The wing keeps the airplane up by pushing the air down.	
	It shoves the air down with its bottom surface, and it pulls the air down with its top surface; the latter action is the more important.	(added sometime after 1990) "How does a symmetrical airfoil create lift?" Question from Nick Frisch during my FlightSafety interview in 1990. My answer: "Newtonian lift."
	In exerting a downward force upon the air, the wing receives an upward counterforce—Newton's law of action and reaction.	
	Sea-level air weighs about 2 pounds per cubic yard. Upward reactions that re equally hefty.	
	A wing is in the last analysis nothing but an air deflector. It is an inclined plane, cleverly curved, to be sure, and elaborately streamlined, but still essentially an inclined plane. That's, after all, why that whole fascinating contraption of ours is called an air-*plane*.	
10	This plane is *inclined* so that as it moves through the air, it will meet the air at an angle and thus shove it downward.	This is why a jet airliner flies decidedly nose-up at high cruise altitudes: to deflect the thin air downward.
	Most training airplanes will maintain level flight comfortably at about two-thirds the usual cruising rpm! All you have to do is hold your nose up by continuous back pressure on the stick.	Minimum Controllable Airspeed = High AoA flying.
11	The Angle of Attack can also be defined as the difference between where the airplane points and where it goes.	Ha! Exactly what I wrote earlier!
	An airplane always flies nose-high, *pointing* up a little higher than it actually *goes.*	

	If it had no Angle of Attack, it would not wash the air down; and if it did not wash the air down, there would be no lift.	
	At the slower speed, the wing catches fewer pounds of air per minute; hence, in order to keep the lift strong enough to hold the airplane up, the air must be deflected more sharply downward; to accomplish this, the wing's angle of attack must be increased.	
	In ordinary flight, the Angle of Attack is so small that the student pilot does not realize its existence; in very slow flight, the Angle of Attack is so large that even the student pilot suddenly realizes what goes on.	Not just *student* pilots (unless we are *all* students).
12	At such high Angle of Attack the control feel is rather different from that of cruising flight.	
	The controls feel different for each different Angle of Attack (or, what is the same thing, for each different speed).	
	In this very slow flight your margin of safety over the stall is much reduced; but as long as you do realize it and act accordingly, there's nothing wrong with that.	
	In the course of ordinary flight training, the student experiences very slow flight rarely, and only for moments at a time.	
	He does not stay in this condition; on the contrary, n all these cases, he tries to get out of it, either trying to stall the airplane, as in landings and stall practice, or else by trying to recover to "normal" flight, as after a premature nose-high take-off. Hence he may come to think that an airplane cannot maintain this flight condition steadily.	
	If he believes that, he misses the main point of the whole art of flying.	(added 2016) Yet the changes to "slow flight" in the Airmen Certification Standards.
13	The entire process of the landing is essentially one of slower and still slower flight, flight at higher and still higher Angle of Attack; all the time exercising very accurate control over the flight path. Yet, at the time when the student first tries landings, he has practically no experience at all in flight at medium or high Angle of Attack. Thus he must learn three things all at once…first, that the airplane *can* fly in this fashion; second, how it responds to the controls in this kind of flight; third, how to judge its flight path so that contact with the ground will be smooth.	(added some time after 1990) This is important in type transition training as well.
	He has to get acquainted with flight at high Angle of Attack under the most difficult condition, that is, near the ground. And he has to get acquainted with the ground under the most difficult condition, that is, while flying at high Angle of Attack.	
	In stall practice, too, the ship goes through the whole range of Angles of Attack rather fast. Such practice may even reinforce the ideas that, whenever the nose is high, a stall will inevitably result.	
	It is worth your while to take your ship up once to a safe altitude and fly it a few minutes in this fashion, maintaining altitude in nose-high flight with very little power.	
	Continue your flight experiment. Open your throttle a bit and then do whatever is necessary to maintain a strictly level flight path. You will relax some of your back pressure against the stick, and the ship will then no longer climb, but the nose will come down lower, and the ship will speed up.	
14	Cruising flight…the airplane now actually goes where its nose is pointing. It might seem as if there were now no Angle of Attack—as if it now maintained flight by some principle other that which keeps it up in "mushing" flight.	Power permits the wing to "process" (deflect) more air per unit of time, hence lower AoA results in the same vertical speed (which may be zero).
15	But there is no other principle. There is an Angle of Attack.	
	With the speed so brisk, an exceedingly small Angle of Attack is enough to produce the necessary lift.	

	You fly upside down by the same principle by which you fly right side up; the wing meets the air at an Angle of Attack and washes it down. Only difference: wing section, used upside down, is inefficient as a down deflector. Hence a large Angle of Attack is needed to produce enough downwash and thus enough lift.	
	The fuselage points level in cruising flight because the designer joined it to the wings at such an angle (the angle of incidence) that, with the wings in level flight at cruising Angle of Attack, it *would* point level!	
16	It is customary to reckon Angle of Attack as the angle that the *chord* of the wing makes with the oncoming air. Chord, in other words, is the reference line. But the chord line is not what really counts in a wing.	And yet that's the FAA definition of AoA: relative to the chord!
	The line that really counts is the *no-lift line*.	
	"Absolute Angle of Attack"—the angle that the no-lift line makes with the oncoming air.	
	The no-lift line of a wing is still at positive Angle of Attack, even in full-power very fast flight.	
	The drag, lifting, and stalling characteristics of such an inclined plane can be improved by surrounding it with a curving, streamlined housing.	
	The actual wing of an airplane is not simply an inclined plane; it is a curved body *containing* an inclined plane. This basic inclined plane *contained* of every wing, is the no-lift line.	
17	In very fast flight, when the inclined plane is working at a very small Angle of Attack, the wing looks, because of its streamlined housing, as if it were at no Angle of Attack, or even at a negative angle. But it only looks that way.	Is this true? How does the air hit the plane inside the housing?
	For every speed, there is one Angle of Attack that will produce just enough lift to hold your ship up. The more speed you have, the less Angle of Attack you need; the less speed you have, the more Angle of Attack you need.	Depends on airplane weight and probably the density altitude.
	The words *speed* and *Angle of Attack* are therefore used almost interchangeably	AoA vs. ASI
18	But weight, too, has something to do with Angle of Attack; if you load more weight into the airplane, then for any given speed it will have to have more Angle of Attack in order to sustain itself in the air.	Anticipated that. Because more lift is needed to overcome weight.
	A stall is not directly caused by lack of speed.	
	It is possible to stall an airplane at speeds very much higher than usual by loading the airplane up excessively with centrifugal force. It is possible to stall your airplane at any speed, even at top speed, simply by pulling the stick back far enough abruptly enough!	Bank matters only if the turn is in level flight. Dive bomber pullout = high AoA. Trying to point the airplane in a direction is cannot go. Load factor, regardless of attitude and bank.
19	Plenty of speed is not necessarily a protection from the stall.	
	It depends on so many factors that it becomes meaningless to say that an airplane stalls because its nose is too high.	
	The direct and immediate cause of any stall is always one thing: *excessive Angle of Attack*—"excessive" meaning, for most wings, greater than 18 degrees.	
	Whenever a wing meets the air at too large an Angle of Attack, and tries to wash it down too sharply, the air fails to take the downward curve. The air flow over the top of the wing burbles and breaks away from the guidance of the wing's curved top surface. The wing is then no longer an efficient downward deflector of the air.	Possibly explains why air molecules that separate at the leading edge do not necessarily have to adjust speed to meet again at the trailing edge, and that there is still lift with some airflow separation from the top of the wing. Where did the "lonely molecules" idea come from?
20	That's what a stall is: the failure of the air to take the downward curve.	
	Simply by pulling the stick back far enough, the pilot can stall his airplane at any speed.	…or pull the stick back *fast* enough. G-load.
	The stall is the direct and invariable result of trying to fly	Stalls are *pilot* (or autopilot) induced.

	the airplane at too large an Angle of Attack.	
	Some speed will be found that is so slow that even a very high Angle of Attack just barely produces enough lift to keep the ship sustained.	That speed is higher with higher wing loading.
21	The air flows at the airplane *not* necessarily horizontally from straight ahead. Hence Angle of Attack cannot be seen simply by looking out the window; in fact, *it cannot be seen* at all!	
	If you want to understand flight, you have to understand the Angle of Attack. And if you want to understand the Angle of Attack, then you have to understand just where, under the various conditions of an airplane's maneuvering, the air comes from which the wing is meeting.	(2016 note) AoA displays do this, but they are not perfect.
22	"Relative wind," this onrush of air, this "wind of flight" always comes at the airplane from the direction toward which the airplane is moving.	But not necessarily where its nose is pointed.
23	When a man first starts flying, he judges mostly by "mechanical" clues; how the nose points above or below the horizon, for example, how his throttle is set; what his instruments show. That is all right to begin with; but those things are not really the most important ones for flight.	(added some time after 1990) Flying "by the numbers" is the starting point, not the end goal.
	As a man goes on and flies more, he discovers skid and slip, and develops a sense for his air speed. But it is still not the most important thing.	Developing "air sense"
	The factor that has to do the most with keeping an airplane up or making it drop, rendering it obedient to the controls or rendering it uncontrollable is the *direction* of the Relative Wind. He is asking himself all the time, "Where, at this moment, is the air coming from? And at what angle are my wings meeting it?"	Just "flying" vs. "air"-manship
24	A good pilot's "feel" for his airplane, his almost instinctive ability to handle it right, is in the last analysis nothing but continual awareness of this most important of all flying facts—the Angle of Attack.	

Chapter 2: "The Airplane's Gaits"

Page No.	Highlighted Text (Langewiesche's words)	My margin notes
25	An airplane…has distinct gaits; it uses sharply different modes of motion at different times	
	Level flight at low Angle of Attack is the airplane's normal gait; that's how it cruises. Its whole design aims primarily at efficiency in cruising flight.	
	Level flight at high Angle of Attack…might be called "Economy flight." An airplane will fly the most *miles* per gallon of fuel when flown rather slowly and nose-high; and it will keep flying the most *minutes* per gallon of fuel if flown very slowly, very nose-high.	
27	This is the gait which the airplane assumes when flown at high altitude. The advantages of "stratosphere" flying are intimately tied up with the economy of this slow, nose-high gait.	
	The dive…flight condition is quite similar to cruising flight; the airplane moves fast, and hence flies at low Angle of Attack.	
	In cruising flight it points and goes level. In a dive, it points and goes down.	
	Vertical dive: almost no upward direction to the wing's lift. Instead, the wings tend to push the airplane along horizontally, parallel to the ground. And since this wing force is not met by any counterforce [weight], the airplane though *pointing* straight down does not actually *go* straight down; it travels quite a distance horizontally as it dives.	

28	The same effect is noticeable even in less steep dives; you pick out a certain field somewhere ahead of you and below you, and dive at it, pointing your nose straight at it; presently the field will disappear underneath your nose.	
29	[Normal glide] The airplane's nose points but slightly down, while its actual flight *path* goes down much more steeply.	
	This "sink" is nothing unhealthy or irregular or dangerous; it is nothing but Angle of Attack, become visible!	
30	The elevator is actually the airplane's Angle of Attack control, and…up and down control is the throttle.	Final approach: **pitch** is airspeed; **power** is vertical speed
	The airplane in a normal glide is going down neither "*because*" the pilot is holding the stick back, nor "*although*" he is holding the stick back. It is going down because the throttle is closed!	
	The position of the stick merely fixes the Angle of Attack and the airspeed at which the airplane flies as it descends.	
	The Mushing Glide is simply descending flight at very low air speed and very high Angle of Attack.	Short field landing
	A…pilot sometimes gets into this flight condition inadvertently, and with exactly the opposite intention: while in a normal glide he tries to "stretch" his glide by pointing his airplane's nose less steeply down than the Normal Glide requires. He then gets exactly what he does *not* want, for as the airplane slows up and goes into a Mushing Glide the larger Angle of Attack means that its descent actually steepens!	
	The airplane will lose the fewest feet of altitude per *minute* when flown at this gait.	
	The airplane can maintain a Mushing Glide with its nose pointing slightly *above* the horizon.	A Mushing Glide is also what happens in a heavy and/or high density altitude takeoff if the pilot tries to pull the nose up too soon or too high.
31	[Stall] is not a flight condition, but is the contrary to flight: the airplane stops flying and starts to fall.	
32	Meeting the air at this excessive Angle of Attack, the wings no longer succeed in deflecting it downward; they merely disturb it. Hence they make no lift.	
33	While [the airplane] drops, it will also nose down—despite anything the pilot may do to keep it from nosing down. It will thus *attempt* to recover speed, *attempt* to reduce its Angle of Attack. If the pilot then relaxes back pressure against his stick and thus allows the flippers [elevators] to return to neutral, the airplane will succeed in making a recovery.	A stall is the result of action by the *pilot*, the *trim*, or the *autopilot* resisting the inherent stall recovery of a stable airplane.
	If the pilot keeps holding the stick back the airplane will *not* succeed in recovery. As long as the pilot keeps holding the stick back, he keeps the airplane at stalling Angle of Attack.	
	That is the real danger of stalling: this faulty reaction to the stall, rather than the stall itself.	Stalls don't kill pilots, poorly planned glides kill pilots.
34	The airplane, once stalled, *must* go down; only by sacrificing altitude can it regain speed quickly enough. And the airplane's stick *must* be allowed to come forward. As long as the stick is too far back, the wings can't make lift.	
	Get the stick forward. *Then* wide-open throttle makes it possible to complete one's recovery with quite small loss of altitude. But the stick must come forward *first*.	You can recover from a stall in a sailplane, or with no power added at all. But you must *push* the controls forward.
	When you are staled, there is one thing that can really help you: accept the inevitable loss of altitude and get the stick forward.	Why it's so hard psychologically to recover from a stall close to the ground, especially a mushing condition in a high density altitude/high weight condition.
	The whole wing will not stall at once. The inner part stalls while the outer part still keeps making lift.	"washout"
35	The nonstalled part of the wing continue to give [the	Aileron input aggravates the stall *only* the

	pilot] lift, stability and control and thus enables him to maintain steady descent. It is an extreme form of the Mushing Glide.	recover is delayed until the *entire* wing stalls. Hence, recover with coordinated rudder *and* aileron.
36	If the climb is fairly shallow, the airplane can maintain, at wide-open throttle, a rather brisk air speed and can therefore fly at moderate Angle of Attack.	"Moderate" AoA = good lift, good climb rate.
	If the climb is steep, the speed will necessarily be slow. And because the speed is so slow only a rather large Angle of Attack can produce enough lift to hold the airplane's weight. Thus the airplane's nose must be carried very high in a steep climb.	
	The Normal Climb will gain the most feet of altitude per *minute*. The Steep Climb will get the most feet of altitude per *mile*.	
38	*Any* climb, even a shallow one, is necessarily made at reduced air speed and hence requires an increase in Angle of Attack.	Lift = AoA + ASI (air speed indicator)
	The observant pilot notices sooner or later that the airplane always seems to "sink" even as it climbs; that it does not actually go up at the angle at which he points it up. [This] is simply Angle of Attack, visible to the eye.	
	The airplane stalls for one reason only: excessive Angle of Attack.	
	For most wing shapes, anything more than about 18 degrees is excessive.	
	The airplane stalls with power on at the same Angle of Attack at which it stalls with power off.	It's just a matter of the difference between where the airplane is *pointed* and where it is *going*, or a function of *excess power*, before it stalls.
40	A power on stall can only occur in a steep climb. That's why the nose is so extremely high in such a maneuver; the nose would be very high even if the airplane were simply in a steep climb. To produce the stall, the nose must be raised even more.	This is *only* valid if "steep" is not tied to the horizon line, but to the direction of the airplane's movement.
	There is really only one kind of stall: the wing meets the air at excessive Angle of Attack.	
	The actual air flow upon which the wing root works is a composite of two winds, Relative Wind and propeller blast.	
	Propeller blast keeps the air flow from burbling at exactly the place where it would tend to burble first if the power were off: near the wing root.	
	The airplane may be brought to a slightly (*very* slightly) higher Angle of Attack with power on than with power off. When the burbling of the air flow finally begins, it doesn't begin near the wing root as it does in a power-off stall, but farther out along the wing, and hence the power-on stall is more likely to lead to sudden loss of lateral stability and loss of control. If the pilot then misuses his ailerons, the stall is more likely to develop into a spin.	So aileron neutral *is* more important in a power on stall.
	The stall-delaying effect of propeller blast is particularly marked in multiengined airplanes. Larger parts of the wing are exposed to propeller blast.	
41	Power descent: The nose points *up*, but the airplane goes *down*. The best way to make a landing approach in a heavy, powerful airplane…a slow mushing glide in which just enough engine power is being used to make the airplane not go down too steeply…. In order to keep the Angle of Attack high and speed slow, the nose must be carried quite high.	
42	Whenever an airplane's flight path is curving, the airplane becomes heavier than it was in straight flight: *g load*.	
	In a 45-degree banked turn, centrifugal force has the same effect as if 40% had been added to the airplane's weight. In a 60-degree banked turn, centrifugal force has the same effect as if the airplane's weight had been doubled.	*If* the turn is level, i.e., the airplane is not forced away from its natural tendency to descend.

43	When an airplane, flying at a given speed, describes a curve it must fly at an *additional* Angle of Attack in order to create the *additional* lift necessary to support this *additional* "weight".	
44	It makes no difference in this respect whether the curve is a curve to the right, to the left, or upward!	All relative to the *airplane* and its direction of flight, not to the horizon.

I'll add more chapter highlights and notes roughly biweekly until we reach the end of the book. If you're impatient—and I hope you are—you won't wait for my musings, but instead will secure your own copy of *Stick and Rudder* now. Beyond simply reading its words, you'll truly analyze, criticize, mark up and understand Langewiesche's teachings to, as Adler suggests, **make this book your own**.

I look forward to your comments on these notes and the larger work. Please send your thoughts to me at mastery.flight.training@cox.net. Thank you.

Pursue *Mastery of Flight.*

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