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Mooney AirVenture 2019

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Preface
AirVenture 2019--Tips to Fly By
by Don Kaye

Although I have flown and taught in many types of aircraft, I can certainly say that I feel lucky to be one of those privileged few to own and fly a Mooney.

Sleek, fast, and efficient, they are not only beautiful to look at, but they glide through the air like a knife slicing through warm butter.

They do require our utmost attention, though. Run your approach just 5 knots too fast and you may wonder where the runway went.

We owe it to ourselves and our passengers to treat the airplane with respect. One word comes to mind when thinking about piloting an airplane---Grace. If you want your passengers to think you are a great pilot, fly your plane like you would dance a waltz in competition. Do it gracefully; light touch on a trimmed airplane, applying control pressures rather than control movements. Make the airplane WANT to do what you want it to do by proper trimming.

Nothing in piloting the airplane has to be rushed. Your passengers should not be able to feel anything you are doing or hear any dramatic changes in engine operation as when changing the RPM. If for some reason you should need to operate a little more quickly, think of the term "casual urgency" when making such changes. Make flying look easy.

Don't over control the airplane in turbulence or when flaring in the landing. In turbulence it can make the turbulence feel worse, and in the flare it not only makes you look like a one armed paper hanger, but can lead to the unintended consequences of a bounced landing or worse, a prop strike.

Landing a Mooney perfectly every time involves proper airspeed control and proper descent management. Nominally, airspeed on approach with full flaps should be 1.3 Vso based on landing weight and the descent path should follow a 3° glide path. Airspeed should be primarily controlled by Pitch and descent rate controlled by the Power. If the nose isn't positioned down at a 3° slope at the time the flare begins, you are not likely to have a perfect landing. Once the flare is begun smoothly allow the airplane to settle as the yoke is brought back in one continuous motion. The rate of pull back is determined by excess lift available and requires practice to make perfect. On a center striped runway you should always be able to see at least 2 stripes ahead as the nose is brought up.

These are a few of the important things I have learned during my past 22 years as a flight instructor.

As a young child, I'd put on my superman cape and jump off chairs hoping to defy the laws of gravity. While that didn't work, my dream of flying was realized many years later with a little more sanity when I got my pilot's license and purchased my Mooney. Even today, over 10,000 flight hours later the wonder of it all hasn't escaped me.

I wish you the same continued excitement of flight in the best Single Engine Piston Airplane ever built, the Mooney.

07/07/2019

Pitch-Power Relationship

For many years I had a specific point of view regarding the Pitch/Power debate. The problem is that Pitch and Power are related when controlling the airplane.

My point of view now is that there should be no debate. At any point in the flight, just determine which is the most important factor related to what you want to control, airspeed or rate of climb or descent and choose pitch as the primary control for that factor (since it is immediate) and power to control the secondary factor.

So, for example, when flying the ILS, slope is most important at airspeeds not near the stall, so pitch would control slope and power would control the airspeed. When on final approach and slowing to near stall, transition to control airspeed with pitch and rate of descent with power. Could you point the nose at the aim point and control airspeed with power? Yes, but because of the long chain of mechanical linkages used to control power, the speed at which the airspeed could be controlled lags considerably from the former approach.

In the end either pitch or power can control airspeed or rate of climb or descent. The more elegant solution to a given situation is to use pitch as the primary control for whatever is most important to you in a given situation, and power for the other.

FROM THE RIGHT SEAT
WITH DON KAYE

Precision Performance

Kinds of Performance

Introduction

- CLIMB PERFORMANCE
- POWER CONTROL
- FUEL/MIXTURE CONTROL
- FLIGHT CONTROL PRECISION
- PARTIAL PANEL CONTROL
- LANDING PRECISION

MAX RATE: WHY IMPORTANT

- **ONE OBVIOUS REASON:** TELLS HOW QUICKLY YOU CAN CHANGE ALTITUDE.
- **NEXT OBVIOUS:** CAN WE CLEAR OBSTRUCTIONS AFTER TAKEOFF?
- **ZERO ROC* ALTITUDE:** ABSOLUTE CEILING; ONLY ONE AIRSPEED USABLE FOR LEVEL FLIGHT.
- **LEAST OVBIOUS:** BEST WAY TO VERIFY POWER OUTPUT STATUS OF PROP/ENGINE!!!

* ROC = RATE-OF CLIMB

FACTORS AFFECTING MAX ROC

- ***NOT CONTROLLABLE BY PILOT*:**
  - **AIR TEMPERATURE & PRESSURE ALTITUDE (DENSITY ALTITUDE)**
  - **CONDITION OF ENGINE, PROP, RIGGING, AERO SURFACES; AND DRAG INDUCING ELEMENTS (ICE, DIRT, ADDED ANTENNAS, ETC)***
- ***PILOT RESPONSIBLE AND/OR SELECTABLE***
  - **PROPER SETTING OF THROTTLE, RPM, MIXTURE, & COWL FLAP**
  - **GEAR & FLAP UP & LOCKED**
  - **AIRPLANE WEIGHT PROJECTED FOR THE CLIMB**
  - **AIRSPEED FOR MAX ROC**

* THESE CAN BE A MAJOR UNKNOWN

HIGH DENSITY ALTITUDE TAKEOFFS

CLIMB PERFORMANCE

THREE KEY PARAMETERS

- **TAKEOFF DISTANCE TO LIFT OFF**
- **TAKEOFF DISTANCE TO CLEAR A 50 FT OBSTACLE**
- **AVAILABLE RATE OF CLIMB AFTER LIFT-OFF**

ON ANY PARTICULAR TAKEOFF, ONE OF THESE IS THE <u>MOST</u> IMPORTANT

TAKEOFF DISTANCES SHOULD TAKE INTO ACCOUNT 7 FACTORS:

- **AIR TEMPERATURE**
- **RUNWAY ROUGHNESS**
- **WIND VELOCITY**
- **AIRPORT PRESSURE ALTITUDE**
- **RUNWAY SLOPE**
- **AIRPLANE WEIGHT**
- **FIXED OR VARIABLE PITCH PROP**

POWER SELECTION PRECISION

PRECISION POWER CONTROL

- PILOTS SHOULD BE COMFORTABLE USING A WIDE RANGE OF POWER SETTINGS CORRECTLY
  - LANDING PATTERNS MAY BE SLOW OR EXPEDITED
  - CRUISE OPTIONS CAN BE FAST, MODERATE, OR ECONOMY
- COMMIT TO MEMORY THE "KEY NUMBERS" FOR QUICKPOWER CHANGES: THESE PROVIDE QUITE ADEQUATE PRECISION
  - "KEY NUMBER" IS THE SUM OF MANIFOLD PRESSURE & RPM (IN 100' S)
  - THESE DO CHANGE SLIGHTLY WITH TEMPERATURE & ALTITUDE, BUT ERROR IS SMALL (UP TO ABOUT 3% POWER
- MINIMUM POWER TO MAINTAIN LEVEL FLIGHT (CLEAN CONFIGURATION IS TYPICALLY 35% RATED POWER.

MIXTURE ADJUSTMENT DISCIPLINE

- PRIOR TO TAXI
- PRIOR TO MAGNETO CHECK
- PRIOR TO TAKEOFF
- DURING CLIMB
- AT CRUISE ALTITUDE
- DURING LET-DOWN
- PRIOR TO LANDING
- AFTER LANDING

- **AT THE TIME OF ANY OTHER POWER CHANGES**

THE PROFICIENT PILOT DOES ALL OF THESE!!!

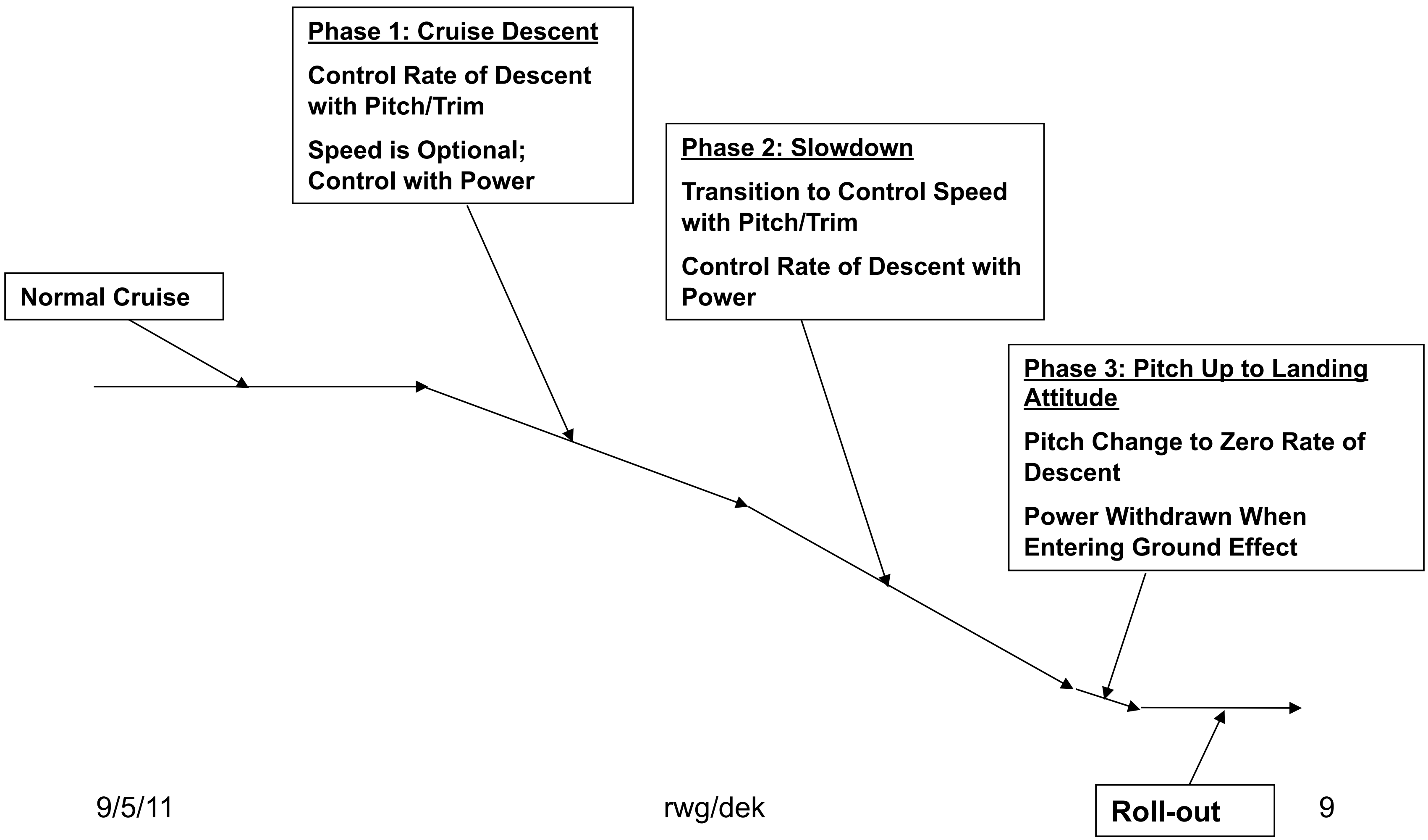
MOST IMPORTANT PAGE IN THIS PACKAGE

FIVE RULES FOR PRECISION FLIGHT CONTROL

FLIGHT CONTROL PRECISION

1. **PITCH CONTROLS *EITHER* <u>SPEED</u> OR <u>RATE-OF-CLIMB/DESCENT</u> (ROC), WHICHEVER IS MOST IMPORTANT, AT ANY PHASE OF FLIGHT.**
2. **THROTTLE CONTROLS *THE OTHER*. (IF PITCH IS PRIME FOR SPEED, THEN THROTTLE CONTROLS ROC.**
3. **IF THE POWER SETTING FOR THE ITEM 2 CONTROL OPERATION (ABOVE) IS PREDETERMINED, THEN MAKE THE POWER CHANGE *WHILE* ACCOMPLISHING THE ITEM 1 CONTROL OPERATION.**
4. **BANK ANGLE CONTROLS RATE-OF-TURN. REMEMBER TWO VALUES:**
   - **STANDARD RATE OF TURN @ 100 KNOTS REQUIRES 15° BANK**
   - **STANDARD RATE OF TURN @ 150 KNOTS REQUIRES 22° BANK**
5. **FOR SMALL HEADING CORRECTIONS (LESS THAN 5°), USE *MAINLY* THE RUDDER.**

THREE PHASES OF A LANDING



AIRSPEED
ENTERING GROUND EFFECT

LANDING PRECISION

AIRSPEED AT TIME OF ENTERING GROUND EFFECT IS THE MOST IMPORTANT PARAMETER FOR PRECISION LANDINGS

- **FINAL APPROACH AIRSPEED SELECTION CONSIDERS FIVE FACTORS:**
  1. **NORMAL OR SHORT FIELD LANDING.**
  2. **GROSS WEIGHT, HEAVY OR LIGHTER.**
  3. **FULL OR NO FLAP DEFLECTION.**
  4. **NORMAL DESCENT POWER, OR POWER WITHDRAWN.**
  5. **SMOOTH AIR, OR ADD AIRSPEED FOR GUST INCREMENT.**

- **EACH OF THE FIVE PARAMETERS PRODUCE 5 TO AS MUCH AS 15 KNOTS CHANGE TO THE OPTIMUM APPROACH SPEEDS.**

- **THE FIVE "DELTA" AIRSPEED CHANGES ADD ALGEBRAICALLY TO PRODUCE THE "OVER THE FENCE" BEST AIRSPEED: SOME ARE ADDED, AND SOME ARE SUBTRACTED.**

OVER-THE-FENCE
PRECISION LANDING SPEED

MODEL	REF. APRCH AIRSPEED	SHORT FIELD	300 LB BELOW GROSS	IDLE POWER	NO FLAPS
SUPER 21 (MPH) [M20E, ‘66]	78	-5	-5	+5	+10
MOONEY 201 (KTS) [M20J, ‘89]	72	-5	-5	+5	+10
MOONEY 252 (KTS) [M20K, ‘87]	75	-5	-5	+5	+8
MOONEY TLS (KTS) [M20M, ‘91]	80	-5	-5	+5	+9

NOTE: ADD OR SUBTRACT EACH OF FOUR ITEMS, AS REQUIRED, FROM REF. APCH. AIRSPEED.; GUST INCREMENT MAY ALSO BE NEEDED.

REF. APCH. AIRSPEED = NORMAL LANDING APPROACH @ MAX GW, WITH NORMAL DESCENT POWER, FULL FLAPS, AND SMOOTH AIR.

PRE TAKEOFF BRIEFING- SINGLE ENGINE

After the runup and before even thinking of taking the runway in a multiengine airplane, a verbal briefing of the actions to be taken in the event of an engine failure on takeoff are stated. It is assumed that an engine is going to fail. Studies have shown that it takes 4 to 6 seconds after an emergency occurs before an action from a pilot begins, either the right one or the wrong one. If it is assumed that a failure will occur, and the actions have been thought out in advance, valuable time is saved when you need it the most. This preflight briefing is even more important to do in a single engine airplane.

The briefing should be verbalized approximately as follows:

1. If I lose the engine before rotation speed (approximately 65 knots in all of our airplanes), I will IMMEDIATELY bring the throttle to idle (the engine could surge unexpectedly), I will bring the elevator full back, and heavily brake to a stop. (Don't takeoff on a runway where the distance to accelerate to this speed and brake to a stop does not give you at least a 50% safety margin (100 percent is better)).

2. If I lose the engine before reaching 1000 feet agl, and no remaining runway, I WILL land straight ahead or make a shallow bank (not greater than 10 degrees) to best avoid ground obstacles. I WILL smoothly lower the nose to best glide speed while verifying the mixture to be full RICH, the prop control to be pulled FULL BACK, the throttle to be FULL FORWARD, the gear UP, the flaps UP, the boost pump ON, and the tanks SWITCHED. I will try a restart. If not restarted, before touchdown I will go to FULL FLAPS, MIXTURE TO FULL CUTOFF, PROP FULL BACK, THROTTLE FULL BACK, AND DOOR OPENED. (Point to each item as you recite the briefing.)

3. If I lose the engine above 1000 feet agl I WILL (you fill in the blank here, as there may be several options; return to field for downwind landing, actually fly the pattern for a landing into the wind, an off field landing... It depends on the area, but you MUST have a plan.

If you have not gone out and experimented with pulling the prop full back you are in for a big surprise. You will pick up at least a 300 fpm reduction in sink rate. No, I have not gone to altitude, cut off the mixture and seen if there is any oil pressure to move the prop. I suspect that unless the engine really got wiped out, the wind milling prop will generate enough oil pressure to move the prop, but I could be mistaken. Has anyone out there done that test?

If you pre brief EVERY takeoff in this manner, you will be putting yourself in the best situation to survive should the "THINKABLE" happen.

Bounced Landings and Prop Strikes

I'd really hate to think that anyone in the Mooney community in the future would have to confess to a prop strike. Eliminating this issue would save us all a lot of money in insurance costs. Every time I see or hear of a prop strike I hope my insurance company isn't involved...but it usually is. And the sad part of all of this is that I don't know of one that wasn't preventable. So, although this has been talked about in the past, I'd like to go over a few things again. First off, I really recommend obtaining copies of the Aviation Safety Series "On Landings" put out by the FAA. The documents are FAA-P-8740-48, FAA-P-8740-49, FAA-P-8740-50. Bounced landings are discussed in detail in Part I, 48. I'm going to give a number of reasons for bounced landings and follow them with the way out. I do one or more of these in every recurrency or aircraft checkout I do, so I know how to bounce them pretty well.

The first easy way to bounce a landing is to come in too fast. If you're going too fast there is no way to achieve the proper landing attitude. You are guaranteed to have a "flat" attitude. The runway zooms by and you push the yoke down to get the plane down. The flexible nose wheel donuts oblige well on "pushdown" by compressing and shooting the plane back into the air nose high. The next usual pilot response is to push the nose back down. Unfortunate, due to brain to muscle delay, the pilot is out of sync, the nose was already going down, and he amplifies the problem and bounces the nose again, only this time harder. He either strikes the prop this time or the same process continues one more time, and the prop strike occurs on the third bounce.

Another good way to have a bounced landing is to have your airplane trimmed nose down on approach, thereby making it difficult to achieve the landing attitude in the flare. You would absolutely not believe how many pilots in the majority of my checkouts fall victim to this situation. On mid final all I have to say is hands off the yoke, and watch a majority of the planes severely pitch down and head for the ground at two or three times the proper approach angle

A third way you might increase your insurance bill is to actually come in too slow for the circumstances. In this situation you have gusty conditions, and just before touchdown a wind gust smashes you into the ground. You get a repeat of the coming in too fast procedure. I had this happen to me several years ago at Palo Alto on a very gusty day. I recovered properly, left my SO on the instructor's bench, and proceeded to go around the pattern about four more times to improve my technique in such circumstances. Not too many people were flying that day, but should have been out with their instructors getting good at the procedure.

Although I've only noticed it in the 231 and Rocket, ground effect reduces somewhat the effectiveness of the elevator due to the decrease in down wash. This makes the elevator a little less effective in ground effect. Therefore, you're increasing the probability of a prop strike, by dropping the airplane into ground effect while letting the speed bleed off in the hopes of not stalling the airplane too high off the ground.

Inattention to airspeed or landing attitude caused by fatigue or other distraction can be another cause of the "bounce". Repeat method one above for a prop strike.

So how can we avoid the results of these situations?

Coming in too fast----To belabor the point once again, maintain proper airspeed control on final. This speed WILL vary with landing weight. Please, always do a quick calculation of your landing weight. This is simple if you start out knowing your zero fuel weight. Then just add the weight of the landing fuel on board and take off 5 knots for each 300 lbs under gross you are. Second, at about 8-10 ft AGL smoothly rotate to the landing attitude (about 8° nose up). Keep pulling back on the yoke to hold that attitude until touchdown. KEEP THE YOKE FULL BACK until you've stopped. The increased drag of the up elevator will assist in braking. If you should bounce on touchdown, NEVER, NEVER, NEVER, NEVER push the yoke forward. Relax back pressure only to the extent of regaining the landing attitude if excess speed is available, or add just enough power to lower the nose to the landing attitude to cushion another bounce if no excess airspeed is available. If your skill level is not up to doing that, then as early as possible add full power and GO AROUND.

Untrimmed airplane----I once had a very good pilot friend of mine say that while you want the airplane to do what you want it to do, what you really want is for the airplane to WANT to do what you want it to do. Trim is the answer. If you really want to become an outstanding pilot, then the first place to improve after a complete understanding of the pitch power relationship in airplanes is in your ability to properly trim your airplane. If you can't trim your airplane hands off and actually have it fly in the desired pitch attitude whether level or other desired attitude such as a stabilized descent, then you will have an inexcusable diversion of attention trying to hold an untrimmed airplane in a specific attitude. That will come back and bite you as an instrument pilot or VFR pilot in heavy workload related situations. Bounced landings are one of them. I emphasize this because, while I can't remember a pilot I have worked with who could trim his airplane hands off when we started training, I also can't remember one who couldn't do it by the time their training was completed. So we are all capable of learning to do it. If your airplane is properly trimmed, then at the proper approach speed, you can easily pitch it to the proper landing attitude and follow method one for recovery from a bounced landing.

Gusty conditions and/or wind shear----The most challenging situation. Since you don't know if you are going to be bounced by the wind, this situation is most demanding. Speed must be increased by at least 1/2 the gust factor, and runway length is critical in the decision to recover as in method one or to go around. If there is any doubt, go around or go to another airport more suitable to the conditions.

If you've experienced fatigue due to lack of sleep or other cause and are planning a cross country for the following day, do yourself and your airplane a favor and don't go. Poor reflexes may turn even the best of pilots and then their airplanes into mush on bounced landings.

If, after reading this material you get only one thing out it, it should be that if you bounce a landing, don't try to recover by pushing the nose down. Almost everyone I've worked with wants to do this. You will always be out of phase with the movement you want to do with the nose of the airplane. Remember, if the nose wheel is off the ground there will be no prop strike. Either hold back pressure to keep the nose up and add power to cushion the next touchdown or add full power and go around.

Now, please, no prop strikes.

Donald E. Kaye, Master CFI 6/8/2015

Speed Brake Use

Speed brakes are just one of many tools that are available in that toolbox of items that can be used for aircraft control. Too often I find that pilots use them without giving much thought about when they are best used. The Mooney is a very efficient airplane and improper use of the speed brakes will just detract from that efficiency.

From my experience speed brakes may best be used in the following circumstances: 1. Slam dunks given by ATC. 2. When asked by ATC to "keep your speed up", no sooner nor later than 5 miles from the airport. 3. For a steep approach to an airport with an obstacle for better slope control without speed increase. 4. To make a quick correction to an approach that has become unstabilized for any reason. 5. To slow down to gear speed in choppy conditions before lowering the gear which is to be used as a rudder to smooth the ride.
6. To assist in slowing down the plane when necessary at other times 7. On a "dive and drive" instrument non-precision approach when not in icing conditions. For the TLS the configuration for descent is 15" MP, Speed Brakes and Gear for a performance of 105 knots and 1000 ft/ min on the descent 8. Immediately AFTER touchdown on a normal landing, but only if the switch is located on the yoke. If it is not on the yoke it could be a distraction at a critical time. Although subjective, I have noticed their effectiveness in the first 10 knots of speed reduction after touchdown.

When should they not be used: Any other time.

I have observed many pilots use them in any descent or just way too early on an approach to an airport. This is really inefficient because no sooner are they at the lower altitude than they have to add power to maintain it. That's just a waste of fuel. When possible, I like to establish a descent of a comfortable 500 ft/min at the top of the green arc. In smooth conditions I'll go to the middle of the yellow arc, keeping my forefinger on the speed brake switch in order to be prepared to deploy them upon encounter of any turbulence in the descent. The speed will quickly be bled off to below the yellow arc.

Others have said they would use them in gusty crosswind landings for stability. I decided to go out and try it. On approach with a crosswind and gusty conditions one day at Tracy Airport I deployed them. A significant downdraft was experienced at about 100 feet AGL. At approach speed deploying the speed brakes will immediately add an additional 200 ft/min rate to the descent. Even with prompt gradual application of full power applied to my TLS, the additional drag associated with the speed brakes could have created a problem had I not retracted them. Lesson learned: don't use the speed brakes in gusty crosswind conditions.

Don't use them to try to "save" a landing when below 100 feet. The immediate 200 ft/min descent rate increase could cause the unwary pilot to damage the gear or worse when the plane slams into the ground. A go around would be the prudent thing to do from an obviously too fast approach.

Don't use them in making a normal approach. You're just using extra power and fuel and could have a problem in a significant downdraft, as I discussed above.

On an instrument approach to a busy airport serving jets, Approach will often ask that the speed be kept up. I'll run the approach gear up to the 5 mile marker at 160 knot speed, "pop" the speed brakes and within a couple of seconds I'll be slowed to gear speed of 140 knots. Additional speed will quickly be bled off to flaps speed of 110 knots. From there I'll apply full flaps, and be slowed to touchdown speed by the large 1,000 foot marker. Regarding shock cooling of the engine, Lycoming says that the cylinders should not be cooled faster than 50°F/min. One can easily remove 5" of MP smoothly at a time and not have that be an issue. I have my MVP 50 alert for the fastest cooling cylinder set at that and rarely have it alert.

While a non known ice TKS airplane should never be flown in icing conditions never, never extend the speed brakes if any ice is encountered. They WILL freeze in the up position.

Always be thinking ahead of the airplane, and don't be too fast to deploy the speed brakes if they really aren't necessary.

Incidentally, if I have a passenger on board, I will always tell them when I am going to add speed brakes so as not to alarm them with the disturbance that accompanies their deployment.

Don Kaye, MCFI 6/8/2015

FLIGHT PROCEDURES IN A CLOSED PATTERN (M20C)

TAKEOFF (NORMAL)

1. Verify wind conditions.
2. Verify takeoff hazards (other planes, runway conditions).
3. Verify proper position of flight controls.
4. Smoothly apply power.
5. Maintain runway centerline.
6. Rotate and liftoff at 70 mph (little wind).
7. Gear UP when an aborted landing can no longer be made.
8. Flaps UP above 200 feet.
9. Maintain pitch attitude for and accelerate to V_y=101 mph.
10. Maintain runway heading ground track through coordinated used of flight controls (use enough RIGHT rudder).

CROSSWIND

1. Turn crosswind 300 feet below pattern altitude.
2. Reduce MP to 16 inches, RPM to 2500 (MP will increase to 18 inches), and lean mixture.
3. Boost pump OFF.
4. Close Cowl flaps.
5. Gear DOWN, flaps 10°.

DOWNWIND

1. Maintain pattern altitude.
2. Maintain Airspeed at 100 Mph.
3. Maintain downwind track compensating for wind.
4. Relax.
5. Abeam the NUMBERS reduce power to 12"MP.
6. Begin descent
6. GUMP check.

BASE

1. Turn base at the 3° slope point with the runway threshold
1. Flaps FULL.
2. Trim for 90 MPH. (Plane will slow due to flap addition)
3. Power as required to maintain 90 MPH.
4. GUMP check again.

FINAL (NORMAL)

1. Precisely maintain RUNWAY alignment.
2. Maintain stabilized approach at 80 MPH (NUMBERS should remain stationary in windshield. If they rise, you are BELOW the glideslope. If the fall, you are ABOVE the glideslope.)
3. Reduce power and begin roundout to landing pitch attitude within 5 to 10 feet above the ground. For center lined runways you should always be able to see at least two stripes ahead. Never raise the nose to such an attitude that the runway ahead cannot be seen.
4. Touchdown in landing pitch attitude on main gear first.
5. Hold back pressure until nose drops and continue to hold back pressure as brakes are applied for minimum stopping distance.

FLIGHT PROCEDURES IN A CLOSED PATTERN (M20F)

TAKEOFF (NORMAL)

1. Verify wind conditions.
2. Verify takeoff hazards (other planes, runway conditions).
3. Verify proper position of flight controls.
4. Smoothly apply power.
5. Maintain runway centerline.
6. Rotate and liftoff at 70 mph (little wind).
7. Gear UP when an aborted landing can no longer be made.
8. Flaps UP above 200 feet.
9. Maintain pitch attitude for and accelerate to V_y=113 mph.
10. Maintain runway heading ground track through coordinated used of flight controls (use enough RIGHT rudder).

CROSSWIND

1. Turn crosswind 300 feet below pattern altitude.
2. Reduce MP to 16 inches, RPM to 2000 (MP will increase to 18 inches), and lean mixture.
3. Boost pump OFF.
4. Close Cowl flaps.
5. Gear DOWN, flaps 10°.

DOWNWIND

1. Maintain pattern altitude.
2. Maintain Airspeed at 100 Mph.
3. Maintain downwind track compensating for wind.
4. Relax.
5. Abeam the NUMBERS reduce power to 12"MP.
6. Begin descent
6. GUMP check.

BASE

1. Turn base at the 3° slope point with the runway threshold
1. Flaps FULL.
2. Trim for 90 MPH. (Plane will slow due to flap addition)
3. Power as required to maintain 90 MPH.
4. GUMP check again.

FINAL (NORMAL)

1. Precisely maintain RUNWAY alignment.
2. Maintain stabilized approach at 80 MPH (NUMBERS should remain stationary in windshield. If they rise, you are BELOW the glideslope. If the fall, you are ABOVE the glideslope.)
3. Reduce power and begin roundout to landing pitch attitude within 5 to 10 feet above the ground. For center lined runways you should always be able to see at least two stripes ahead. Never raise the nose to such an attitude that the runway ahead cannot be seen.
4. Touchdown in landing pitch attitude on main gear first.
5. Hold back pressure until nose drops and continue to hold back pressure as brakes are applied for minimum stopping distance.

FLIGHT PROCEDURES IN A CLOSED PATTERN (M20K)

TAKEOFF (NORMAL)

1. Verify wind conditions.
2. Verify takeoff hazards (other planes, runway conditions).
3. Verify proper position of flight controls.
4. Smoothly apply power.
5. Maintain runway centerline.
6. Rotate and liftoff at 65 knots (little wind).
7. Gear UP when an aborted landing can no longer be made.
8. Flaps UP above 200 feet. (Don't raise flaps if remaining in the pattern)
9. Maintain pitch attitude for and accelerate to V_y=96 knots
10. Maintain runway heading ground track through coordinated used of flight controls (use enough RIGHT rudder).

CROSSWIND

1. Turn crosswind 300 feet below pattern altitude.
2. Gear DOWN first to act as a brake, flaps 10°.
3. Reduce MP to maintain 90 knots and lean mixture (usually between 20-22 inches).

DOWNWIND

1. Maintain pattern altitude.
2. Maintain Airspeed at 90 knots
3. Maintain downwind track compensating for wind.
4. Relax.
5. Abeam the NUMBERS reduce power to 15"MP.
6. Begin descent
7. GUMP check.

BASE

1. Turn base at the 3° slope point with the runway threshold
1. Flaps FULL. (Do NOT let the nose drop below 3°)
2. Trim for 80 knots. (Plane will slow due to flap addition)
3. Power as required to maintain 70 knots
4. GUMP check again.

FINAL (NORMAL)

1. Precisely maintain RUNWAY alignment.
2. Maintain stabilized approach at 70 knots nominally (NUMBERS should remain stationary in windshield. If they rise, you are BELOW the glideslope. If the fall, you are ABOVE the glideslope.)
3. Reduce power to idle and simultaneously begin roundout (flare) to landing pitch attitude within 5 to 10 feet above the ground. For center lined runways you should always be able to see at least two stripes ahead. Never raise the nose to such an attitude that the runway ahead cannot be seen.
4. Touchdown in landing pitch attitude on main gear first.
5. Hold back pressure until nose drops and continue to hold back pressure as brakes are applied for minimum stopping distance.

FLIGHT PROCEDURES IN A CLOSED PATTERN (M20R, M20M, or M20TN)

TAKEOFF (NORMAL)

1. Verify wind conditions.
2. Verify takeoff hazards (other planes, runway conditions).
3. Verify proper position of flight controls.
4. Smoothly apply power.
5. Maintain runway centerline.
6. Rotate and liftoff at 65 knots (little wind).
7. Gear UP when an aborted landing can no longer be made.
8. Flaps UP above 200 feet. (Don't raise flaps if remaining in the pattern)
9. Maintain pitch attitude for and accelerate to V_y=105 knots
10. Maintain runway heading ground track through coordinated used of flight controls (use enough RIGHT rudder).

CROSSWIND

1. Turn crosswind 300 feet below pattern altitude.
2. Gear DOWN first to act as a brake, flaps 10°.
3. Reduce MP to maintain 90 knots and lean mixture (usually between 18-22 inches).

DOWNWIND

1. Maintain pattern altitude.
2. Maintain Airspeed at 90 knots
3. Maintain downwind track compensating for wind.
4. Relax.
5. Abeam the NUMBERS reduce power to 14"MP.
6. Begin descent
7. GUMP check.

BASE

1. Turn base at the 3° slope point with the runway threshold
1. Flaps FULL. (Do NOT let the nose drop below 3°)
2. Trim for 80 knots. (Plane will slow due to flap addition)
3. Power as required to maintain 80 knots
4. GUMP check again.

FINAL (NORMAL)

1. Precisely maintain RUNWAY alignment.
2. Maintain stabilized approach at 75 knots nominally (NUMBERS should remain stationary in windshield. If they rise, you are BELOW the glideslope. If the fall, you are ABOVE the glideslope.)
3. Reduce power to idle and simultaneously begin roundout (flare) to landing pitch attitude within 5 to 10 feet above the ground. For center lined runways you should always be able to see at least two stripes ahead. Never raise the nose to such an attitude that the runway ahead cannot be seen.
4. Touchdown in landing pitch attitude on main gear first.
5. Hold back pressure until nose drops and continue to hold back pressure as brakes are applied for minimum stopping distance.

Important Instrument Rating Information

Instrument Rating and Re-currency Overview

Competent instrument flying is composed of the following:

1. Flying best reference heading. If you cannot hold a heading, you will never be able to fly an acceptable approach, make wind corrections or pass an IPC.
2. For new or non-current instrument pilots, the 6 T's are a must. They must be performed with mental clarity, in the proper order, and not just run through mechanically. They are: Turn, Time Twist, Throttle, Talk, Track. Additionally, use the MARTHA's checklist as a guide to all instrument approaches. Each letter stands for the following: M-missed approach procedure. A-Altimeter Setting. R-Radios (approach frequencies, compass locator, marker beacons, radar alt, approach/tower frequencies), T-Time if the approach is a timed approach H The inbound heading A-Altitude (minimum altitude on the approach).
3. Have the time available to be able to ask yourself the question: "What else can I do?" Having this time available means your scan is fast enough to allow for the accomplishment of more tasks. The more excess tasks that can be performed, the more competent the instrument pilot. Failure to be able to accomplish sufficient (or any) excess tasks precludes the pilot from being an acceptable instrument pilot.

Approach Charts

5 Steps to know on each approach

1. Identify <u>All Radials</u> 6-8 sec
2. Look at Critical Chart <u>Headings</u> 6-8 sec
3. What are Critical <u>Altitudes</u> 6-8 sec
4. Final Approach Preparations
   1. How many miles from FAF to 2 miles from threshold
   2. Calculate time to 2 miles from threshold
   3. Calculate rate of descent from FAF to MDA
   4. Identify to what <u>Heading</u> to turn to make the landing
5. Missed Approach Procedure 6-8 sec
   1. Climb to What <u>Altitude</u>
   2. Turn to What <u>Heading</u>

7 Parameters of a Holding Pattern

1. Define Fix
2. Direction from Fix
3. Radial on which to Hold
4. Altitude to Hold
5. Direction of Turns
6. EFC (Expect further Clearance) Time
7. Length of each Leg

Holding Pattern Procedure and Maneuvers

1. Sketch Holding Pattern
2. Verify against copied Clearance
3. Note on the drawn pattern the <u>Heading</u> of the <u>Outbound</u> leg.
4. Identify your position with respect to Holding Pattern Location

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Revised 7/5/02

5. Heading of the Outbound leg should agree with the direction of the Hold
6. Draw 70˚ line with respect to the Inbound Leg of Holding Pattern
7. Identify the entry quadrant
8. If not a direct entry, i.e. teardrop, sketch the teardrop entry leg and note the heading of the teardrop entry leg
9. If a parallel entry, sketch the intercept leg and its heading on the chart

Enroute Navigation

1. Identify Navigation Aids
2. Identify Headings
3. Identify Altitudes
4. Identify ETA
5. Identify Communications Frequencies
6. While flying (1-5) leg establish in your mind the same 5 items for the next leg

On Flying Turbulence

It was the latter part of November 1964. I had gone down to San Diego over the Thanksgiving Holiday and was returning to College in Berkeley. It would be another four years before I would even be thinking of getting my Private Pilot's License. In those days you could get a one way ticket on PSA for $19.99. The weather was absolutely terrible that morning. You knew it was bad when the airlines were taking off to the East, and they were taking off to the East on that day. PSA was using the four engine Electra Turboprops at that time. They did not go all that high, and on this day we would be slogging alone at 24,000 feet after a stop in LA. I did hesitate getting on the plane that morning, but I did it anyway. Immediately after the first takeoff I was slammed into the seat as we hit a huge updraft. After landing in LA, I seriously considered getting off and taking the bus, but I needed to get back to classes so I stayed aboard.

I will never forget the next hour and a half. Even at that time I guess I was smart enough to chose to be near the wing and the center of gravity for the best ride. There was no best place that day. It rained and rained and the clouds were so thick that when I looked out at the wing, I couldn't see it most of the time. When I could see it, what I saw made me want to close my eyes. The severe turbulence was creating torsion on the wing that caused bending it in all kinds of directions and the engines were moving in ways that made me feel very uncomfortable, if it was possible to feel any more uncomfortable. Wings had been known to depart the Electras before they were strengthened. The flight attendants were trying to calm petrified passengers and were handing out sick sacks like they were going out of style. A friend next to me asked to " borrow" mine. He and just about everyone on the flight were not doing well. I may have been the only one not to get sick, but if I had had to stay on the plane another 15 minutes… I can't tell you how many people were asking or rather begging, "When were we going to land?" When I finally saw water, I thought we were crashing. Instead we were on final approach to SFO. On landing there were numerous ambulances waiting to take off some very sick people. After all these years, that was the worst plane ride I have ever experienced to date. So I have a baseline for me of how bad turbulence can be.

I think it is a good idea to have a worse case baseline that you won't forget. If you rode alone with me in the above example and have not experienced anything so bad, then let that be your baseline without having to experience it. The Electra was not a small plane and yet it was treated like a tin can in a swirling ocean. That should be a lesson to us. There is a big ocean of air out there and in our small airplanes we are like a small molecule in it. So most importantly, if you want your passengers to fly with you again, then you want to do everything possible to keep them comfortable and that means trying to avoid at best or minimize in the least, turbulence.

The best way to minimize it is to not come in contact with it. This means studying and becoming as knowledgeable as you can about weather phenomena. There are many good aviation weather books, and I would read as many of them as you can. Some of the ones that I have found most useful are "Severe Weather Flying" by Dennis Newton and "Weather Flying" by Robert Buck. The purpose of reading those books is not to go out and fly the types of weather discussed, but to understand the conditions that create turbulent weather and thus avoid flying it. This applies to both VFR and IFR pilots. The instrument rating allows you to become competent flying in some instrument conditions, but at least from my experience, many types of instrument conditions should not be flown in our type of airplanes. Becoming a "weather expert" and applying good aeronautical decision making skills to that knowledge will keep you from taking unnecessary risks with the weather. Rarely, if ever, should you be surprised by the weather you have chosen to fly.

Weather comes in basically two types: convective and non convective. This was not something I fully understood when I got my Private License. Understanding when each is likely to occur will go a long way toward staying clear of, or at least being able to mitigate the effects of, turbulence. Obviously, you want to stay clear of convective activity (thunderstorms), and certainly you don't want to fly your airplane IMC in it. With the up to date weather products available to us in flight today, there is no reason to end up in heavy convective activity. By far, it's best to fly early in the morning and be done flying by noon, especially in the mountains and the mid west.

So, we've done our preflight planning, and determine that while it is safe to go, the probability is that along our route of flight we can expect some turbulence. This is discussed with your passengers, if any. You tell them the expected magnitude and your plan to mitigate it. They agree to go.

About a half hour into the flight and on the autopilot you experience light chop that becomes increasingly worse. The first method of mitigation is to disconnect the autopilot and "hand fly" the airplane. We can hand fly the airplane much, much better than the autopilot can fly it, however, it is very important not to over control. Go with the flow and remember, "less is better" when it comes to control movements. I often see people making the ride much worse by trying to correct for every bump. Don't. There comes a time when even the most proficient pilot can't smooth the ride satisfactorily.

The next method of mitigation is to climb. Oftentimes a few thousand feet can make all the difference. If the turbulence is eliminated, then go back to the autopilot. If it's not, but it is not too uncomfortable, then continue to hand fly.

If you've run out of an acceptable altitude to which to climb, then it's time to reduce speed gradually to maneuvering speed. This will "soften" the effects of the bumps both on the passengers and the airplane. Depending on the severity of the turbulence and passenger discomfort, it might be time to consider calling it a day and landing.

Should turbulence be any worse than just discussed (and that is just below moderate), I would recommend not having passengers on board. In addition to fearful passengers, the stress on the pilot worrying about his passengers is a distraction that can impact flying performance.

For moderate turbulence, there are additional mitigations. Leaving Farmington, New Mexico one cold winter morning on the way to a Cleveland band venue in a student's Ovation, the winds were 35 gusting to 45 on takeoff. There are mountains to the East on the way to Oklahoma City, our next stop. The Ovation is a great airplane, but climbing to 17,000 feet is a chore. We stayed at 15,000 feet and had moderate or greater turbulence that was expected. So, the next method of mitigation is to extend the gear. This acts as a rudder of sorts and stabilizes the plane. And finally, as a last method of mitigation for those who have them, extending the speed brakes also acts to stabilize the plane. We alternately were extending and retracting both the gear and speed brakes for nearly 5 hours in the worst turbulence I have experienced over a prolonged period of time in a light airplane.

While flying in smooth air is like I would imagine a magic carpet ride to be, the above turbulence mitigate techniques will go a long way towards acquiring a passenger following on those days where a less proficient pilot might lose such a following. Know your weather and turbulence signals and chose your flying days wisely.

Don Kaye, Master CFI

Investigation of a General Aviation Differential Pressure Angle of Attack Probe‡

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Abstract

A wind tunnal calibration of a commerically available general aviation differential pressure angle of attack probe was conducted. Differential pressure varied linearly with pitch angle for each dynamic pressure tested. Beyond ±6° of yaw angle, differential pressure rolled off rapidly with yaw angle. Normalizing differential pressure with dynamic pressure collapsed the differential pressure to a single curve for pitch. Similarly, normalizing differential pressure with the dynamic pressure collapsed the differential pressure to a single curve for yaw. Normalizing the differential pressure with dynamic pressure removes the effect of speed and density altitude when deriving angle of attack from differential pressure.

Normalizing the differential pressure using the pressure from the 45° probe surface similarly collapsed the differential pressure to single separate curves for both pitch and yaw. Differential pressure varied parabolically with pitch angle when normalized using the pressure from the 45° probe surface. For pitch angles above six degrees, a linear relation between differential pressure normalized with the pressure from the 45° probe surface and the square of the pitch angle provided an adequate approximation.

The typical two-point linear approximation based on two in-flight calibration points results in significant errors in displayed angle of attack. Moving the low angle of attack in-flight calibration point closer to the stall angle of attack reduces the displayed angle of attack error in the critical stall region. Using a four-point linear approximation significantly reduces the error in displayed angle of attack throughout the angle of attack range.

Combined pitch, yaw and roll results in sideslip, which produces significant error in displayed angle of attack based on calibration at zero yaw and roll.

‡ This article is based on the AIAA Jounal of Aircraft paper, Rogers, David F., *Investigation of a General-Aviation Differential Pressure Angle-of-Attack Probe*, Journal of Aircraft, Vol. 50, No. 5 (2013), Sept-Oct. 2013, pp. 1668-1671 with further extensions.

Nomenclature

a	=	lift curve slope
b	=	wing span
C_L	=	aircraft lift coefficient
D	=	aircraft drag
e	=	Oswald efficiency factor
EAS	=	equivalent aircraft speed
f	=	aircraft equivalent parasite drag area
L	=	aircraft lift
$L/D_{\max}$	=	maximum lift to drag ratio
$\mathrm{P}_{\mathrm{fwd}}$	=	pressure on probe forward port
P_{45}	=	pressure on probe 45° surface
q	=	dynamic pressure
R^2	=	square of the correlation coefficient
S	=	wing reference area
V	=	true airspeed
V_{CC}	=	Carson cruise speed
$V_{L/D\max}$	=	maximum lift to drag speed
$V_{P_{R_{\min}}}$	=	minimum power required speed
V_{stall}	=	stall speed
W	=	weight of the aircraft
α	=	angle of attack
α_{CC}	=	angle of attack for Carson cruise speed
$\alpha_{L/D\max}$	=	angle of attack for $L/D_{\max}$
$\alpha_{P_{R_{\min}}}$	=	angle of attack for minimum power required
ϕ	=	roll angle
θ	=	wind tunnel pitch angle
ρ	=	density
ρ_{SL}	=	density at sea level
σ	=	ratio of the density at altitude to that at sea level, ρ/ρ_{SL}

Introduction

Recently there has been renewed interest in equipping light general aviation aircraft with angle of attack instrumentation. The Federal Aviation Administration has facilitated this effort by declaring the addition of angle of attack instrumentation as a minor modification provided that certain conditions are met. The key condition is: "The installation of the angle of attack system does not require interface with the existing pitot-static system; the installation does not require direct pressure input from the pitot-static system."[Sad11]. This requirement dictates that the angle of attack system stand alone.

The typical light general aviation angle of attack system measures a differential pressure and interprets the result as angle of attack. Because of flow field effects, in-flight calibration is necessary. Typically the differential pressure at two flight conditions, e.g., near stall and in cruise, are used as in-flight calibration points. The angle of attack is interpreted using a linear variation between the differential pressures at the two in-flight calibration points. A wind tunnel investigation was undertaken to determine the accuracy of this method.

The Probe

The probe tested is a typical commercial differential pressure angle of attack probe. Typically the probe is mounted on the bottom of the wing of a single engine aircraft, as shown in Figure 1, or on the underside of the nose of a twin engine aircraft. When mounted under the aircraft wing the probe extends forward and downward at a nominal 45° degree angle to the wing surface. Provision is provided to re-orientate the probe at 5° increments from 35° to 90° to aid in-flight calibration

Figure 1. Angle of attack probe mounted under the wing.

The probe contains two pressure ports, each 0.1" in diameter. One pressure port, called P_{fwd} in Figure 2, is nominally aligned with the airstream direction under the wing. In high speed cruise flight P_{fwd} nominally measures total pressure. The second pressure port, called P_{45} in Figure 2, is located on the flat 45° surface. The differential pressure $\Delta P = P_{fwd} - P_{45}$ is related to angle of attack. Conceptually, this is similar to the classical spherical or cylindrical based differential pressure angle of attack probe (see for example Gracey [Gra58] and Arend and Saunders [Are09] and the references therein).

The Wind Tunnel

The tests were conducted in the United States Naval Academy's open circuit induction or "Eiffel" wind tunnel. In this tunnel the discharge from the exit is returned to the inlet within the laboratory in which the tunnel is housed. The tunnel was designed to have low turbulence. Turbulence is controlled by using a contraction ratio of 9.6, a 1/4 inch wide by six inch thick aluminum honeycomb screen at the entrance of the contraction section followed by four stainless steel 20×20 per inch mesh screens. Forty-five degree fillets are installed, beginning at the test section entrance and continuing through the test section into the diffuser to compensate for boundary layer growth. The ten foot long enclosed test section accommodates two balances. The upstream test section is equipped with a pyramidal balance while the downstream test section contains a sting balance. When the sting balance is in use the upstream model supports are removed and a flush plate fitted to the test section floor. The balance enclosure is sealed to equalize the enclosure pressure with the test section pressure. Hence, flow around the model supports is eliminated. The nominal test section size is 44w × 31h inches. Dynamic pressure in the test section is measured using static pressure rings in the settling chamber just prior to the contraction and just upstream of the test section. The tunnel constant is 1.0303. The turbulence factor is 0.98.

The Tests

The angle of attack probe was mounted in the sting balance, as shown in Figure 3. The forward pressure port was aligned with the centerline of the test section at zero pitch and yaw angles. Pressure at the forward pressure port (P_{fwd}) and the pressure port on the 45° surface (P_{45}) were measured

Figure 2. Pressure port locations.

Figure 3. Angle of attack probe mounted in the wind tunnel.

on an alcohol manometer inclined at 29.6°. Pressure measurments were read with an accuracy of 0.05 ± 0.025"alcohol on the inclined scale. The tunnel dynamic pressure was read on a variable inclination inclined manometer. The accuracy of the variable inclination inclined manometer is ¼%. The manometer fluid was alcohol with a specific gravity of 0.811. The dynamic pressure was read to an accuracy of 0.05"alc.

The parallel arm pitch mechanism on the sting balance maintained the P_{fwd} pressure port of the model in a three-dimensional space 2 inches in the flow direction × 4 inches wide and × 4½ inches high in the center of the nominally 44 × 31 inch test section, for pitch and yaw angles of ±24° and ±20° respectively. Tunnel wall effects are considered negligible.

The tunnel was equipped with a computerized system to maintain constant dynamic pressure in the test section. Accuracy, varified by observation of the variable incidence alcohol dynamic pressure manometer, was within ±0.1"alc.

The Results

The probe was pitched through ±6° at zero yaw and yawed through ±6° at zero pitch at one degree intervals to establish a baseline. The pressure difference $P_{fwd} - P_{45}$ varied linearly with pitch angle and was constant with yaw angle throughout the limited test range.

Tests were conducted for a range of pitch and yaw angles at nominal dynamic pressures of 9.33, 15.35, 25.7 and 42.17 psf, which nominally correspond to equivalent airspeeds of 88.6, 113.6, 147.0, 188.3 fps. These dynamic pressures and equivalent airspeeds are within the range between stall and $V_{L/D\max}$ for typical light general aviation aircraft.

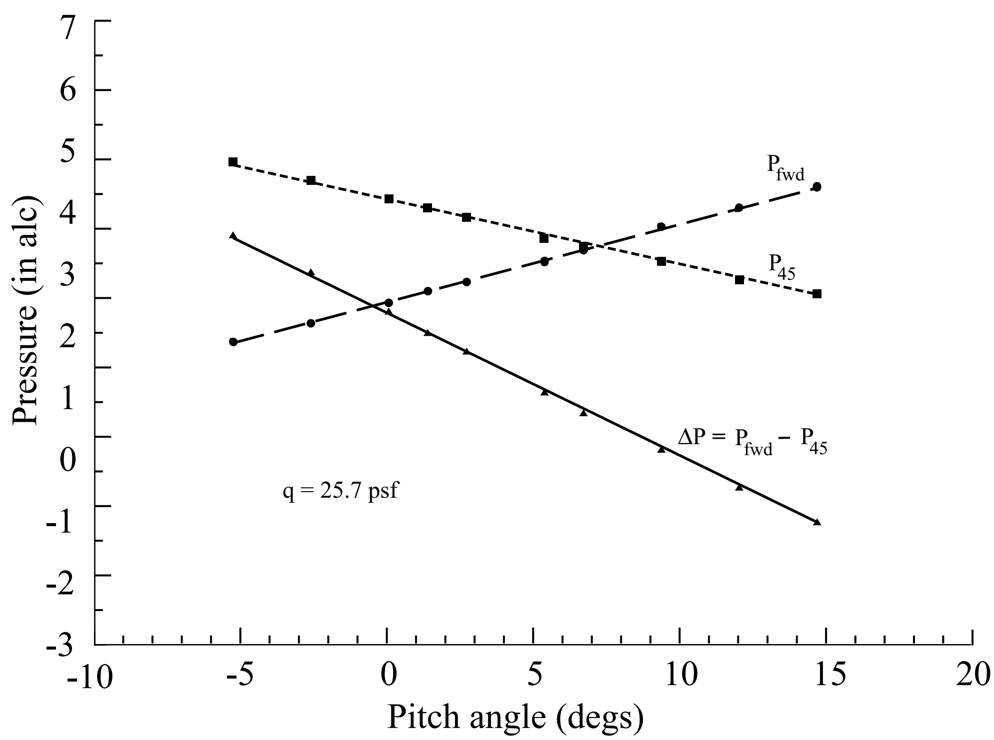


Figure 4. Raw pitch data for P_{fwd}, P_{45} and $P_{fwd} - P_{45}$ for a nominal dynamic pressure of 25.7 lb psf.

Pitch

Figure 4 shows the raw data as read from the inclined manometer for P_{fwd}, P_{45} and $P_{fwd}-P_{45}$ as a function of pitch angle for a dynamic pressure of 25.7 psf. Clearly, these pressures vary linearly with pitch angle. The results for dynamic pressures of 9.33, 15.7 and 42.17 psf are similar. Figure 5 compares $P_{fwd}-P_{45}$ for dynamic pressures of 9.33, 15.7, 25.7 and 42.17 psf. As is easily seen, there is a significant effect of the dynamic pressure on the accuracy of the indicated angle of attack for a given differential pressure $P_{fwd}-P_{45}$. For example, if the differential pressure $P_{fwd}-P_{45}$ is -1"alc the corresponding angles of attack are 10.2, 11.2, 13.0 and 16 degrees for dynamic pressures of 9.33, 15.7, 25.7 and 42.17 psf. Significant error in the angle of attack results in the critical low speed/stall flight region.

As expected, and as shown in Figure 6, normalizing the differential pressure using the dynamic pressure collapses the data in Figure 5 to a single straight line. However, acquiring the dynamic pressure requires access to the aircraft pitot-static system, which is not acceptable to the Federal Aviation Administration (FAA) [Sad11] without significant certification effort and expense.

Yaw

Figure 7 shows the raw data as read from the inclined manometer for P_{fwd}, P_{45} and $P_{fwd}-P_{45}$ as a function of yaw angle for a dynamic pressure of 25.8 psf. Notice that the differential pressure is essentially constant for yaw angles of $\pm 6°$. The results for nominal dynamic pressures of 9.33, 15.7 and 42.17 psf are similar. Again, as with the pitch results, a significant dynamic pressure effect is observed.

Figure 8 shows that normalizing the results using the dynamic pressure collapses the data to a single curve although not as well as for pitch. Again, the normalized differential pressure is essentially constant for yaw angles of $\pm 6°$. However, it falls off significantly for yaw angles larger than 10°. For example, from Figure 8 at a yaw of $+10°$ yields $(P_{fwd}-P_{45})/q = 0.27$. Using the normalized zero yaw and roll calibrarion curve for $(P_{fwd}-P_{45})/q = 0.27$ yields an angle of attack of 1°, i.e., a 9° error in the displayed angle of attack. Furthermore, the displayed angle of attack is lower than the actual angle of attack which is non-conservative.

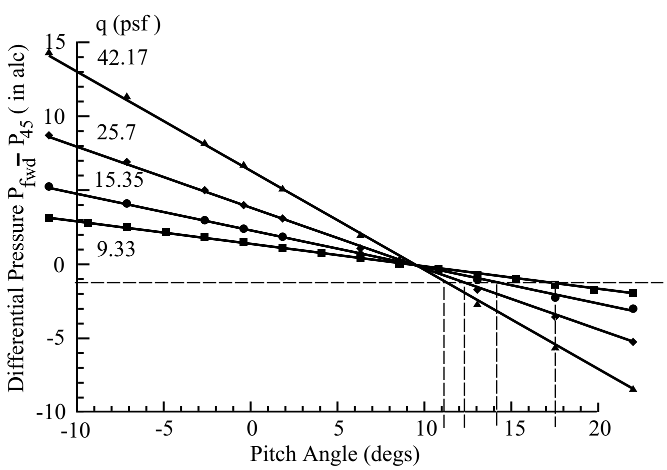


Figure 5. Comparison of the pitch differential pressure, $P_{fwd}-P_{45}$, for various dynamic pressures.

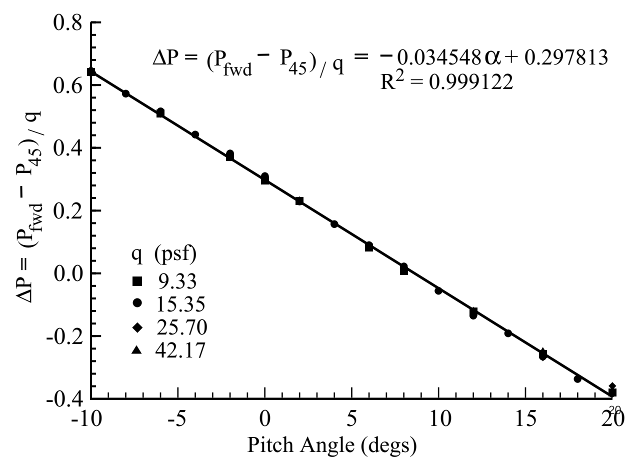


Figure 6. Pitch differential pressure normalized by dynamic pressure $(P_{fwd}-P_{45})/q$.

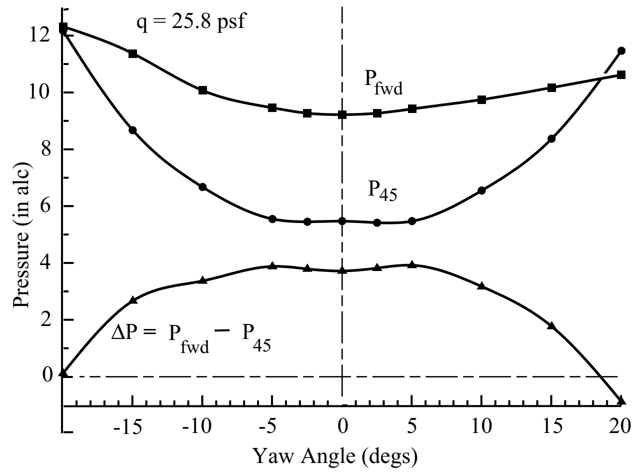


Figure 7. Raw yaw data for P_{fwd}, P_{45} and $P_{fwd}-P_{45}$ for a nominal dynamic pressure of 25.8 psf.

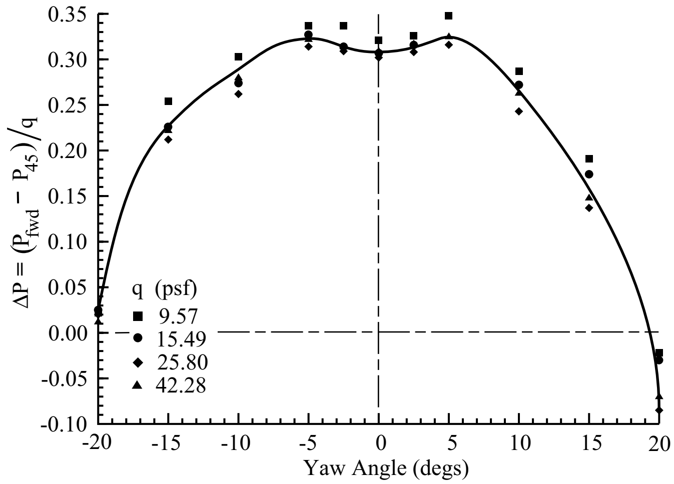


Figure 8. Yaw differential pressure normalized by dynamic pressure $(P_{fwd}-P_{45})/q$.

Flight Line

In order to determine the error in angle of attack it is necessary to determine the flight angle of attack as a function of flight conditions specifically as a function of equivalent airspeed (EAS). From

$$C_L = a\alpha = \frac{2W}{\rho_{SL}(EAS)^2 S} \qquad \text{we have} \qquad \alpha = \frac{1}{a}\frac{2W}{\rho_{SL}(EAS)^2 S} \tag{1}$$

In terms of the equivalent airspeed the dynamic pressure is given by

$$q = {}^1\!/\!{}_2\rho_{SL}(EAS)^2 \tag{2}$$

Recall the equation for the normallized differential pressure for the angle of attack probe is

$$\frac{\Delta P}{q} = \frac{P_{\text{fwd}} - P_{45}}{q} = m_1\alpha + b_1 = -0.034548\alpha + 0.297813 \tag{3}$$

From these three equations the differential pressure sensed by the angle of attack probe can be determined as a function of angle of attack as shown in Figure 9 and labelled “Flight Line”. For typical angles of attack from high speed cruise to near stall the Flight Line varies approximately parabolically.

There are four angles of attack that are of importance to pilots of light general aviation aircraft ($W \leq 6000$ lbs). These are the stall angle of attack and those for maximum lift to drag ratio, minimum power required and economical high speed cruise, i.e., the Carson cruise speed [CAR82]. The stall angle of attack is important for an obvious reason: the pilot would like to avoid stalling the aircraft. The angle of attack for maximum lift to drag ratio is important because it represents both the condition for best glide and best range for a piston powered aircraft. The angle of attack for minimum power required represents the condition for maximum endurance as well as the dividing line between the regions of normal and reverse command. The Carson cruise angle of attack represents the optimal condition for high speed cruise with minimum increase in fuel flow per unit time. In each case, for a given aircraft configuration, these angles of attack depend only on aircraft design parameters and are independent of weight and altitude. To see this, consider the angle of attack for maximum lift to drag ratio. Recall that the true airspeed for $L/D_{\max}$ is

$$V_{L/D\max} = \left(\frac{2}{\sigma\rho_{SL}}\frac{W}{b}\frac{1}{\sqrt{\pi f e}}\right)^{1/2} \tag{4}$$

or in terms of the square of the equivalent airspeed

$$(\text{EAS}_{L/D\text{max}})^2 = \frac{2}{\rho_{\text{SL}}}\frac{W}{b}\frac{1}{\sqrt{\pi f e}} \tag{5}$$

Rewriting Eq.(1) for L/D_{max} yields

$$(\text{EAS}_{L/D\text{max}})^2 = \frac{2}{a\alpha}\frac{1}{\rho_{\text{SL}}}\frac{W}{S} \tag{6}$$

Equating Eqs.(5 and 6) and solving for the angle of attack for L/D_{max} yields

$$\alpha_{L/D\text{max}} = \frac{1}{a}\frac{b}{S}\sqrt{\pi f e} \tag{7}$$

which, for a given aircraft configuration, depends only on aircraft design parameters and is independent of weight and altitude.

Similarly, recalling that the velocities for minimum power required and for Carson cruise [CAR82] are

$$V_{P_{R_{\text{min}}}} = \frac{1}{\sqrt[4]{3}}V_{L/D\text{max}} \qquad \text{and} \qquad V_{\text{CC}} = \sqrt[4]{3}\,V_{L/D\text{max}}$$

the corresponding angles of attack are

$$\alpha_{P_{R_{\text{min}}}} = \sqrt{3}\,V_{L/D\text{max}} \qquad \text{and} \qquad \alpha_{\text{CC}} = \frac{1}{\sqrt{3}}V_{L/D\text{max}} \tag{8}$$

For a typical light general aviation retractable gear aircraft with $a = 0.083$/deg, $b = 33.5$ ft, $S = 181$ ft^2, $f = 3.125\,\text{ft}^2$ and $e = 0.56$ the angles of attack are

$$\alpha_{L/D\text{max}} = 5.23°; \qquad \alpha_{P_{R_{\text{min}}}} = 9.06°; \qquad \alpha_{\text{CC}} = 3.02°$$

(see [ROG10] for additional information on the aircraft). These angles are shown on the flight line in Figure 9.

Effect of Two-Point Linear Calibration

Typically, simple differential pressure based angle of attack probes use a 2-point calibration with linear interpolation between the two calibration points, as previously mentioned. The dashed line in Figure 9 shows the resulting calibration line when the Carson speed and a speed 10% above stall speed are used as the calibration points. The gray shaded area illustrates the error in displayed angle

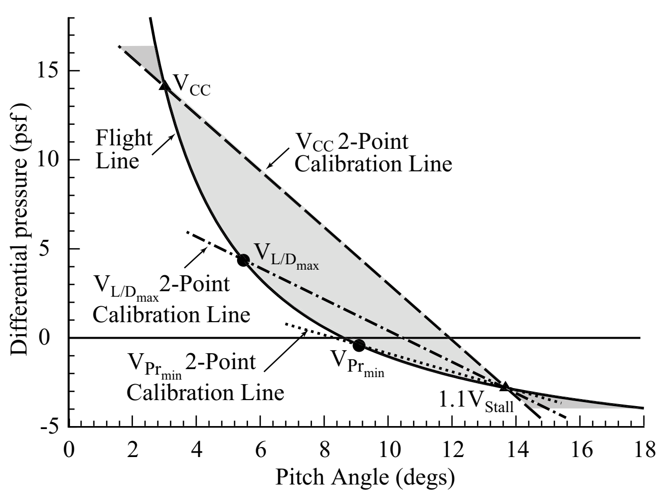


Figure 9. Flight line and the effect of 2-point linear calibration.

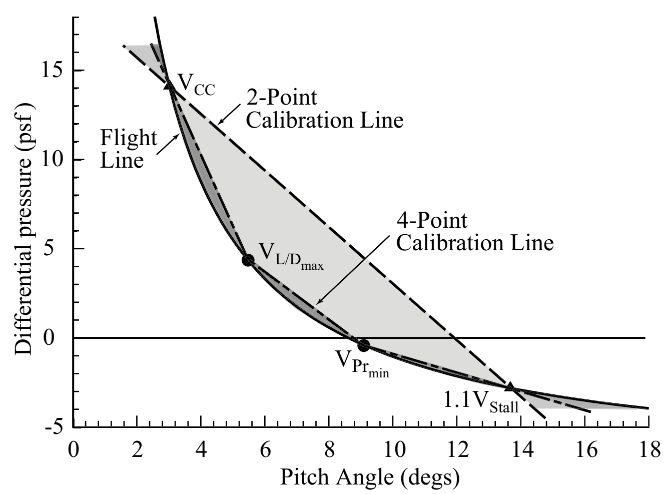


Figure 10. Comparison of 2-point and 4-point linear calibration.

of attack that results from this technique. This error can be significant. For example, at a differential pressure reading of 5 psf the actual angle of attack as read from the flight line is approximately 5.2° while the displayed angle of attack as determined by the calibration line is approximately 8.7°, an error of 3.5°. Between the calibration points the displayed angle of attack overestimates the actual angle of attack. At the calibration points the error reduces to zero. Outside of the calibration points, linear calibration underestimates the angle of attack. This is particular egregious in the stall region. As illustrated in Figure 9, moving the high speed calibration point closer to the stall region calibration point at $1.1V_{\text{stall}}$ reduces the error, as shown by the chain dashed line through $V_{L/D\text{max}}$ and the dotted line through $V_{P_{R_{\text{min}}}}$ and $1.1V_{\text{stall}}$, especially in the stall region. However, the error in the high speed region to the left of the flight line is increased.

An Improved Calibration Technique

Figure 9 suggests an improved calibration technique using four points with linear interpolation between the points. The result using V_{CC}, $V_{L/D\text{max}}$, $V_{P_{R_{\text{min}}}}$ and $1.1V_{\text{stall}}$ as the calibration points is shown in Figure 10, along with the 2-Point calibration. For comparison, the error between the flight line angle of attack and the 4-Point calibration is shown as a darker shaded area. As expected, the error in displayed angle of attack and the flight line angle of attack is considerably smaller.

Alternate Normalization Techniques

The calibration techniques mentioned above do not account for the dynamic pressure effects shown in Figure 5. Because the FAA does not consider an angle of attack system on a general aviation aircaft that accesses the aircraft pitot-static system (see [Sad11]) a minor alteration, an alternate method of normalizing the differential pressure independent of the aircraft pitot-static system is shown in Figure 11. Here, the differential pressure ($\Delta P = \text{P}_{\text{fwd}} - \text{P}_{45}$) is normalized using the pressure from the 45° surface. Figure 11 clearly shows that the results for all four dynamic pressures tested collapse into a single parabolic curve. Similar results, not shown, are obtained by normalizing P_{fwd} by P_{45}, i.e., $\text{P}_{\text{fwd}}/P_{45}$. Writing the equation for $\Delta P/P_{45}$ in Figure 11 as

$$\hat{a}\theta^2 + \hat{b}\theta + \hat{c} = 0 \tag{9}$$

where $\hat{a} = -0.001304$, $\hat{b} = -0.040428$, and $\hat{c} = 0.426844 - \Delta P/P_{45}$ the pitch angle, θ, which

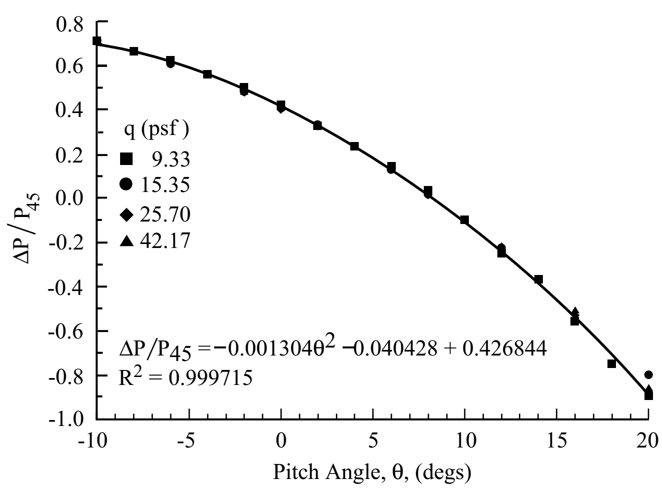


Figure 11. Alternate method of normalizing the differential pressure.

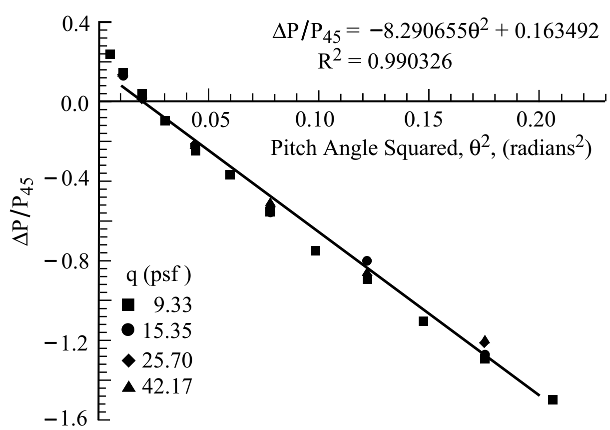


Figure 12. Approximate variation of differential pressure with pitch angle squared.

corresponds to the aircraft angle of attack, α, is simply

$$\alpha = \theta = -15.5 \pm \sqrt{240.3 + 766.9\hat{c}} \tag{10}$$

Careful consideration must be given to insure that the resulting angle of attack is within the normal operating range for the particular aircraft. For example, for a non-aerobatic aircraft the angle of attack should be positive. It is suggested that in-flight calibration using the four points discussed above, specifically V_{CC}, $V_{L/D\text{max}}$, $V_{P_{R_{\text{min}}}}$ and $1.1V_{\text{stall}}$, is adequate to provide an aircraft specific calibration.

The parabolic variation of $\Delta P/P_{45}$ with angle of attack suggests that assuming a linear variation of $\Delta P/P_{45}$ with the square of the angle of attack might be useful. Figure 12 shows the results for positive angles of attack greater than approximately six degrees. Figure 12 shows that the approximation is least accurate for low and medium angles of attack, i.e., for the cruise phase of flight, and reasonably accurate for higher angles of attack, i.e., in the critical flight regime approaching stall. Writing the equation in Figure 12 as

$$\bar{a}\theta^2 + \bar{c} = 0 \tag{11}$$

where $\bar{a} = -8.29065$ and $\bar{c} = 0.163492 - \Delta P/P_{45}$, the angle of attack and pitch angle are then simply

$$\alpha = \theta = \sqrt{\frac{(0.163492 - \dfrac{\Delta P}{P_{45}})}{0.8290655}} \tag{12}$$

The accuracy in the critical near stall regime is on the order of $\pm 0.5^\circ$.

Combined Pitch, Yaw and Roll Effects

If the probe is not yawed or pitched but only rolled about the free stream direction, then there is little or no effect on the differential pressure measured and hence on the angle of attack indication. However, if the probe is simultaneously pitched and rolled then a yaw, or more properly a sideslip, results. Figure 13 illustrates this effect. In Figure 13 the probe has been pitched 25°, yawed 10° and rolled 45° for illustrative purposes. The flow direction is perpendicular to and into the image. Clearly, the effective yaw or sideslip is greater than 10°.

Simultaneous Pitch and Roll

Figure 14 shows that, when simutaneously pitched and rolled, for roll angles up to an order of 12–15° the error in normalized differential pressure is reasonably small. However, above these values the error increases significantly. For example, for a typical aircraft at the dynamic pressure of 25.91 psf(≈100 MIAS) given in Figure 14 the angle of attack in level flight might be 8.5°. Recall that the angle of attack varies as $1/cos(\phi)$. If the aircaft is rolled (banked) to a 45° bank angle, then the angle of attack required to maintain level flight is $8.5/\cos(45) = 12^\circ$. However, interpolating between the orange dots in Figure 14, the normalized differential pressure measured by the probe is approximately 0.1. The pitch (angle of attack), based on the zero yaw and roll calibration curve shown in black in Figure 14, interprets this pressure as approximately 6.6° (see Figure 11), a significant error. The system thus displays a much lower angle of attack. This is not conservation if the aircraft is close to stall.

Simultaneous Pitch and Yaw

Figure 15 illustrates, when simultaneously pitched and yawed, for yaw angles up to on the order of 7.5° that the error in the normalized differential pressure is again reasonably small. Above 7.5° the error increases dramatically, albeit in a conservative direction, i.e., the angle of attack display shows a value greater than the actual angle of attack. Again, using the typical aircraft cited above for an

Figure 13. Angle of attack probe pitched 25°, yawed 10° and rolled 45°. The viewpoint is directly into the image.

angle of attack in level flight of 8.5° and interpolating between the ×s in Figure 15 for a 15° yaw angle, the normalized differential pressure is approximately −0.21. The calibation curve for zero yaw and roll interprets this as an angle of attack of approximately 11.8°. This is still a significant error but conservative because it results in the display of an angle of attack larger than actual. For larger yaw angles, which are unlikely outside of aerobatic flight, the errors are considerably larger.

Comparing Figure 14 and Figure 15 shows that the effects of yaw and roll are opposite. Specifically, Figure 14 shows that as the probe is rolled while simultaneously pitched the normalized differential pressure increases with increasing roll angle. Hence, the displayed angle of attack is smaller than the angle of attack derived from the zero yaw and roll calibration curve represented by the solid black line. However, Figure 15 shows that as the probe is yawed while simultaneously pitched, the normalized differential pressure decreases with increasing yaw angle. Hence, the displayed angle of attack is larger than the angle of attack derived from the zero yaw and roll calibration line. This leads us to look at simulataneous pitch, yaw and roll.

Simultaneous Pitch, Yaw and Roll

Figure 16 shows the effects of simulataneously pitching, rolling and yawing the probe for roll angles of 15° and 30° and yaw angles of 5°, 10°, 15°, and 20° compared to the normalized differential pressure calibration curve for zero roll and yaw represented by the solid black line. As expected from Figures 14 and 15, the effect of moderate roll and yaw angles is mixed.

For a roll angle of 15° and yaw angles of 15° and 20° the displayed angle of attack derived from the zero yaw and roll calibration line is larger than the actual angle of attack. However, for yaw

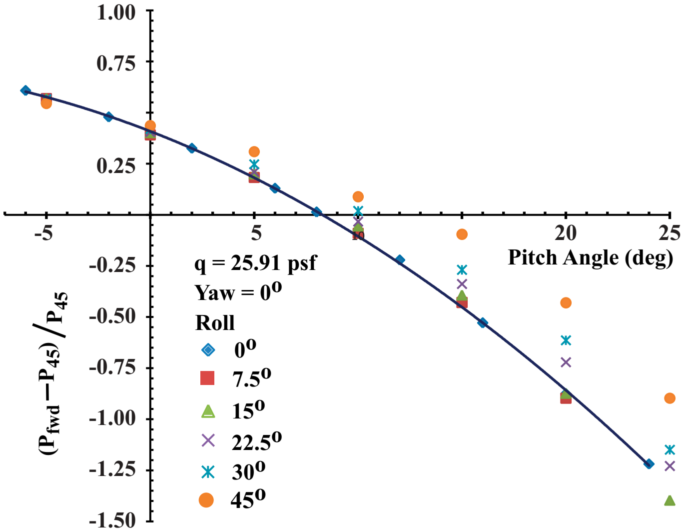


Figure 14. The effect of simultaneous pitch and roll on normalized differential pressure $(P_{fwd}-P_{45})/P_{45}$ for $q = 25.86$ psf.

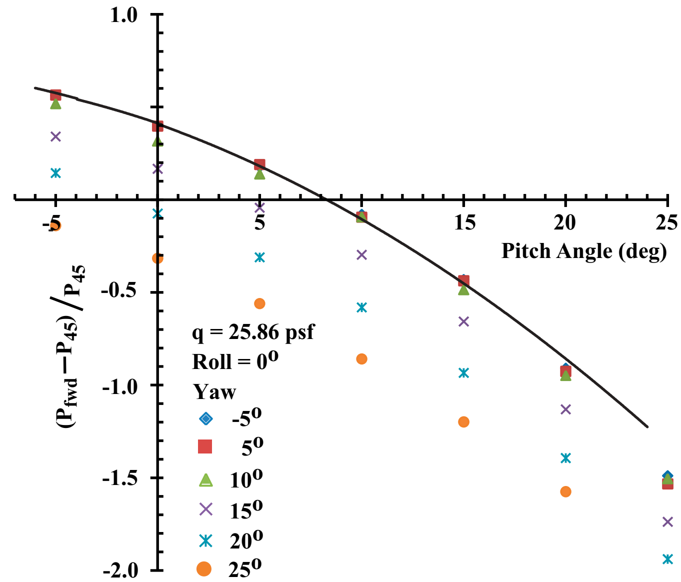


Figure 15. The effect of simultaneous pitch and yaw on normalized differential pressure $(P_{fwd}-P_{45})/P_{45}$ for $q = 25.86$ psf.

angles of 5° and 10° the displayed angle of attack is smaller than the actual angle of attack. Again, using a typical aircraft with a dynamic pressure of approximately 25.86 psf(≈ 100 MIAS) at zero yaw and pitch the angle of attack is 8.5°. Banked 30° the actual angle of attack is approximately 9.8°. From Figure 16b the displayed angle of attack is consistently smaller than the actual angle of attack.

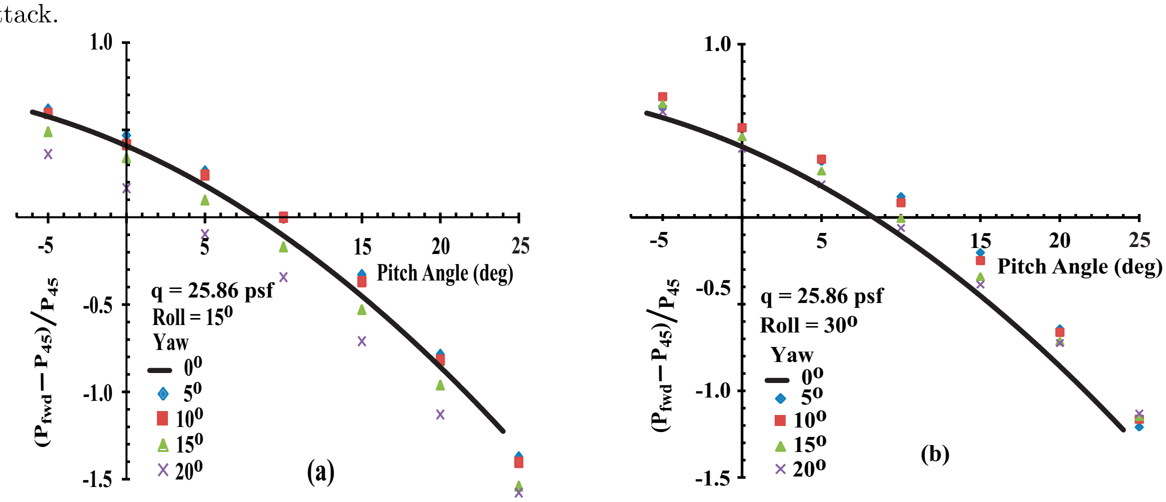


Figure 16. Effect of combine pitch, yaw and roll on the normalized differential pressure for a dynamic pressure of 25.86 psf≈100 MIAS; (a) roll = 15°, (b) = 30°

Conclusions

A wind tunnel calibration of a commerically available general aviation differential pressure angle of attack probe in both pitch and yaw was conducted. The differential pressure varied linearly with pitch angle for each dynamic pressure tested. The differential pressure was basically independent of yaw within ±6°. Beyond ±6° the differential pressure rapidly rolled off, introducing significant errors beyond ±10°. The measured differential pressure was significantly affected by dynamic pressure. Normalizing the differential pressure by dynamic pressure collapsed the data to a single linear relation in pitch angle. It was discovered that normalizing the differential pressure by the pressure on the probe-inclined surface also collapsed the data but in this case to a single parabolic relation in terms of the pitch angle. Finally, it was discovered that in the range from approximately $V_{L/D_{\max}}$ to stall a linear relation between $\Delta P/P_{45}$ with the square of the pitch angle provided an adequate approximation to the pitch angle.

The typical implementation of a differential pressure based angle of attack probe assumes a linear variation in angle of attack with differential pressure based on a 2-point in-flight calibration. Typically one calibration point is in cruise flight and the other near stall. This assumption results in significant errors in displayed angle of attack except at and near the calibration points. For angles of attack beyond the calibration points the displayed angle of attack is lower than the actual angle of attack. Between the calibration points the displayed angle of attack is higher than the actual angle of attack. Moving the high angle of attack calibration point closer to the stall angle of attack reduces the error in the stall region. Furthermore, moving the low angle of attack calibration point closer to the stall angle of attack also reduces the error in the critical stall region.

The wind tunnel tests suggest that a 4-point in-flight calibration procedure, using the speeds for Carson cruise [CAR82], maximum lift to drag ratio, power required minimum (maximum endurance) and 110% of stall, results in a significant reduction in displayed angle of attack throughout the angle of attack range.

Combined pitch, yaw and roll angle of attack yields mixed results when comparing displayed angle of attach and actual angle of attack for practical combined angles of yaw and bank.

References

Sad11 Letter from the FAA Small Airplane Directorate, Kansas City, KS, to DepotStar Inc. dated 15 December 2011.

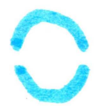
Gra58 Gracey, W, "Summary of Methods of Measuring Angle of Attack on Aircraft," NACA TN-4351, August 1958.

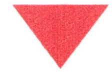
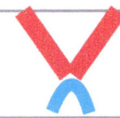
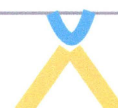
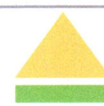
Are09 Arend, D. J. and Saunders, J. D., "An Experimental Evaluation of the Performance of Two Combination Pitot Pressure Probes," NASA Technical Paper TP-2009-215632M, October 2009.

CAR82 Carson, B. H., "Fuel Efficiency of Small Aircraft," *Journal of Aircraft*, Vol. 19, 1982, pp. 473–479.

ROG10 Rogers, D. F.,"Flight Determination of Partial-Span-Flap Parasite Drag with Flap Deflection," *Journal of Aircraft*, Vol. 47, 2010, pp. 551–555.

Actual weight	3210
Max gross	3368
Adjustment Factor	.9763

Speed	Max Gross	Calculated	Actual	AOA Indication
Vso	59	57	57	
Vs1	66	64	64	
Vx	85	83	83	
Vref	75	73	73	
Vy	105	103	103	
Vglide	90	89	89	
Va	110	108	108	

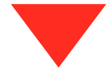
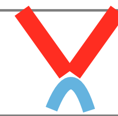
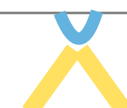
	Clean	1/2 Flaps Gear Down	Full Flaps Gear Down
	60-61		
	62-64	58-59	56-58
	65-66	60-65	59-62
	67-69	66-67	63-66
	70-72	68-72	67-69
	73-77	73-77	70-75
	78-80	78-81	76-78
	81-85	82-87	79-84
	86-93	88-93	85-91
	94-99	94-99	92-96
	100-102	100-103	97-99
	103-105	104-105	100-103
	106+	106+	104+

Actual weight 3210

Max gross 3368

Adjustment Factor .9763

Speed	Max Gross	Calculated	Actual	AOA Indication
Vso	59	57	**57**	
Vs1	66	64	**64**	
Vx	85	83	**83**	
Vref	75	73	**73**	
Vy	105	103	**103**	
Vglide	90	89	**89**	
Va	110	108	**108**	

	Clean	1/2 Flaps Gear Down	Full Flaps Gear Down
	**60-61**		
	**62-64**	**58-59**	**56-58**
	**65-66**	**60-65**	**59-62**
	**67-69**	**66-67**	**63-66**
	**70-72**	**68-72**	**67-69**
	**73-77**	**73-77**	**70-75**
	**78-80**	**78-81**	**76-78**
	**81-85**	**82-87**	**79-84**
	86-93	**88-93**	**85-91**
	94-99	**94-99**	**92-96**
	100-102	**100-103**	**97-99**
	**103-105**	**104-105**	**100-103**
	**106+**	**106+**	**104+**

5/24/15

XM Weather Products vs ADS-B Products

	XM	ADS-B	
Nexrad	Yes	Yes	ADS-B high resolution with 250 miles lower resolution beyond
Satellite	Yes	No	
Winds Aloft	Yes	Yes	
Lightning	Yes	No	
Storm Cells	Yes	No	
Metars/TAF	Yes	Yes	
Airmet	Yes	Yes	
Sigmet	Yes	Yes	
TFR	Yes	Yes	
Pirep	Yes	Yes	
Freezing Level	Yes	Yes	
Weather Forecast	Yes	No	
Notams	No	Yes	
Special Use Airspace	No	Yes	

ADS-B may not be received on the ground
ADS-B does not cover the whole US at present

Engine Monitor Data Analysis Report

Client: Donald Kaye
Aircraft: N9148W
Flight: 2015-06-04

A/C Type: Mooney M20M Bravo
Engine: Lycoming TIO-540
Monitor: Electronics International (E...

Report Date: 2015-06-06
Subscr. ends: 2016-06-04

Client Comments

The flight was specifically flown to perform the test profile. I flew the test profile twice as requested. For the lean Mag Check I might have leaned the engine too much as it ran very rough. My annual is at the end of the month, so I appreciate your analysis.

Summary of Findings

GAMI sweep results indicate slightly poor mixture distribution. An additional last sweep showed 0.8 GPH spread with a slightly erratic FF. 2 & 5 are consistently your leanest and richest running cylinders; respectively with no outliers observed. On the last sweeps, Injectors 2 & 6 shows signs of being a bit dirty, but not bad. LOP mag check was too quick to assess. RPMs are excellent, delivering full rated horsepower. MAP is within Mooney's spec of 34" to 38" but slightly low per Lycoming TCDS which specifies 35" at sea level to 36.5" at critical altitude of 20K'. CHTs are good. TIT temp is good. Engine Monitor data is good. EI data sample interval is 1 secs. Powerplant management is ok. Bus voltage is high at 28.4 to 28.5v.

GAMI Lean Test

N/A (no usable mixture sweeps observed)

Sweep #1
Time: 00:28:53-00:30:05
EGT2 peaked at 11.4
EGT6 peaked at 11.4
EGT3 peaked at 11.2
EGT4 peaked at 11.2
EGT1 peaked at 11.1
EGT5 peaked at 11
GAMI spread is 0.4

Sweep #2
Time: 00:30:33-00:31:45
EGT2 peaked at 12.3
EGT4 peaked at 12
EGT6 peaked at 12
EGT1 peaked at 11.6
EGT3 peaked at 11.6
EGT5 peaked at 11.6
GAMI spread is 0.7

Sweep #3
Time: 00:36:27-00:39:00
EGT2 peaked at 11.8
EGT6 peaked at 11.7
EGT1 peaked at 11.6
EGT4 peaked at 11.5
EGT3 peaked at 11.3
EGT5 peaked at 11.3
GAMI spread is 0.5

Observations
Savvy likes to see a GAMI spread of 0.5 GPH or lower. The average for these sweeps is at the top of the range that we like to see for smooth LOP operations.

Ignition — Caution

Non-firing plug(s):
Marginal plug(s):
Split mag timing:
Add'l observations: Mag Check was too quick to assess

Max Power — Caution

Max power FF: 30.6 GPH
Max power RPM: 2580 vs. 2575: Good
Maximum MAP: 34.2" vs per Lyc 35" SL to 36.5": slightly low
Add'l observations:

Temperatures — Satisfactory

CHTs: 304-325 in climb, 301-332 in cruise
EGTs:
TIT(s): 1447 in climb, 1565 in cruise
Add'l observations:

Engine Monitor — Satisfactory

Inoperative sensors: Oil Press, Oil Temp, Fuel Press, OAT all OK
Anomalous channels: None
Noisy channels: None
Add'l observations:

Powerplant Mgt — Satisfactory

Power: Good
Mixture: Good
Test Profile(s): LOP Mag test too short; appears too lean
Add'l observations:

Electrical — Caution

Primary sys: 28.4v to 28.5v vs 27.5v to 28.2v: High
Secondary sys:
Other sensors: AMPS Good
Add'l observations:

Recommendations:

GAMI spreads might be improved by cleaning injectors; especially 2 & 6. Suggest re-running the LOP mag check to enable us to assess the ignition system for you. Recommend allowing the EGTs to stabilize once LOP before beginning (helps set a baseline for comparison), then begin with the left Mag. Allow EGTs to stabilize again on Both before proceeding with the Right only mag. The profile ask for 1 min in order to get 10 data points but with your sampling rate 10-15 sec should be ok. To help the roughness, a FF below 10 (vs 8) at the same 2400 and 21.5" may be sufficient LOP for the Mag test. (Or the minimum LOP FF where roughness is tolerable.) We suggest adjusting bus voltage within the range of 27.5 to 28.2v for battery longevity. --PK

SAFO

Safety Alert for Operators

U.S. Department
of Transportation
**Federal Aviation
Administration**

SAFO 15006
DATE: 5/19/15

Flight Standards Service
Washington, DC

http://www.faa.gov/other_visit/aviation_industry/airline_operators/airline_safety/safo

A SAFO contains important safety information and may include recommended action. SAFO content should be especially valuable to air carriers in meeting their statutory duty to provide service with the highest possible degree of safety in the public interest. Besides the specific action recommended in a SAFO, an alternative action may be as effective in addressing the safety issue named in the SAFO.

Subject: Transponder Use by Aircraft On Airport Movement Areas

Purpose: This SAFO advises all operators and pilots of the need to ensure that transponders are in the altitude reporting mode whenever their aircraft is on an airport movement area at all airports.

Background: The Federal Aviation Administration (FAA) uses airport surface surveillance capabilities at some of the busiest airports in the U.S. to determine aircraft and vehicle location when they are operating on an airport movement area. Runway safety systems, such as Airport Surface Detection Equipment-Model X (ASDE-X) and Advanced Surface Movement Guidance and Control System (A-SMGCS), use data from surface movement radar and aircraft transponders to obtain accurate aircraft and vehicle locations, thereby increasing airport surface safety and efficiency.

Discussion: As the FAA transitions to the Next Generation Air Transportation System, some Airport Surface Detection Equipment-Model 3 systems will be replaced with a multilateration (MLAT)[1]/Automatic Dependent Surveillance–Broadcast (ADS-B) system, called Airport Surface Surveillance Capability (ASSC). This capability fuses MLAT sensor data with ADS-B aircraft information on FAA certified airport tower controller displays, tracks surface vehicles and aircraft providing information for Air Traffic Control (ATC) services, and is capable of providing data to other external FAA systems,[2] including compliance monitoring capabilities.

The effectiveness of ASSC and ASDE-X is dependent on operators equipping and operating cooperative surveillance capabilities (i.e., altitude reporting transponders). Nationwide, airports with ASDE-X report an average of twenty non-compliance transponder events per day, even with airport diagram or Automated Terminal Information Service (ATIS), or both, verbiage directing pilots to operate with transponders on. To proactively address these problems, aircraft operating on all airport movement areas at all airports, not just those that are ASDE-X equipped, must have their transponders on in the altitude reporting mode.

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[1] MLAT provides accurate position and identification information by determining an aircraft or vehicle's location based on the time difference between transponder/transmitter signals received at multiple sensors.

[2] E.g., Surveillance Broadcast Services and Runway Status Lights.

Recommended Actions: Operators should ensure that their procedures and manuals clearly state that flightcrews and general aviation (GA) pilots enable transponders to the altitude reporting mode (consult the aircraft's flight manual to determine the specific transponder position to enable altitude reporting) and enable ADS-B Out transmissions (if equipped) any time their aircraft is positioned on any portion of an airport movement area. This includes all defined taxiways and runways on all airports. Flightcrews and GA pilots must, per Title 14 of the Code of Federal Regulations (14 CFR) part 91 §91.9, part 121 §121.141 and part 135 §135.21, ensure that they comply with these procedures and manuals as well as pay particular attention to ATIS, Aircraft Communications Addressing and Reporting System (ACARS) messages, airport diagram notations, and General Notes (included on Jeppesen Airway Manual charts) which direct them to comply with directions pertaining to transponder and ADS-B usage.

Generally, these directions state:

- Departures. Select the transponder mode which allows altitude reporting and enable ADS-B (if equipped) during pushback. Select TA or TA/RA (if equipped) when taking the active runway.
- Arrivals. Maintain or select (if TA or TA/RA equipped) transponder to the altitude reporting position and maintain ADS-B Out transmissions (if equipped) after clearing the active runway. Select STBY or OFF for transponder and ADS-B (if equipped) upon gate arrival.

Operators and GA pilots should ensure their checklists reference transponders in the following places:

- "Before Starting Engines" or "Pushback" checklist
  TRANSPONDER……………………………… Select the altitude reporting mode
  ADS-B…………………………………………. Enabled (if equipped)

- "Before Takeoff" checklist
  TA or TA/RA (if equipped)…………………….Enabled

- "After Landing" checklist
  TRANSPONDER……..……………………… .Select the altitude reporting mode
  ADS-B………………………………………… Enabled (if equipped)
  TA or TA/RA……………………………..…Disabled

- "Parking" or "Shutdown" checklist
  TRANSPONDER………………………………STBY/OFF
  ADS-B………………………………………….STBY/OFF (if equipped)

> **Note:** Both flightcrews and GA pilots should continue to comply with procedures relating to transponder operation which may be harmful to ground personnel (e.g., de-icing of Predictive Wind Shear (PWS) equipped aircraft).

Contact: Questions or comments regarding this SAFO should be directed to the Air Transportation division, Part 121 Air Carrier Operations Branch, AFS-220 at (202) 267-8166.