

Spins and how to keep the pointy end of the airplane going forward

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Outline

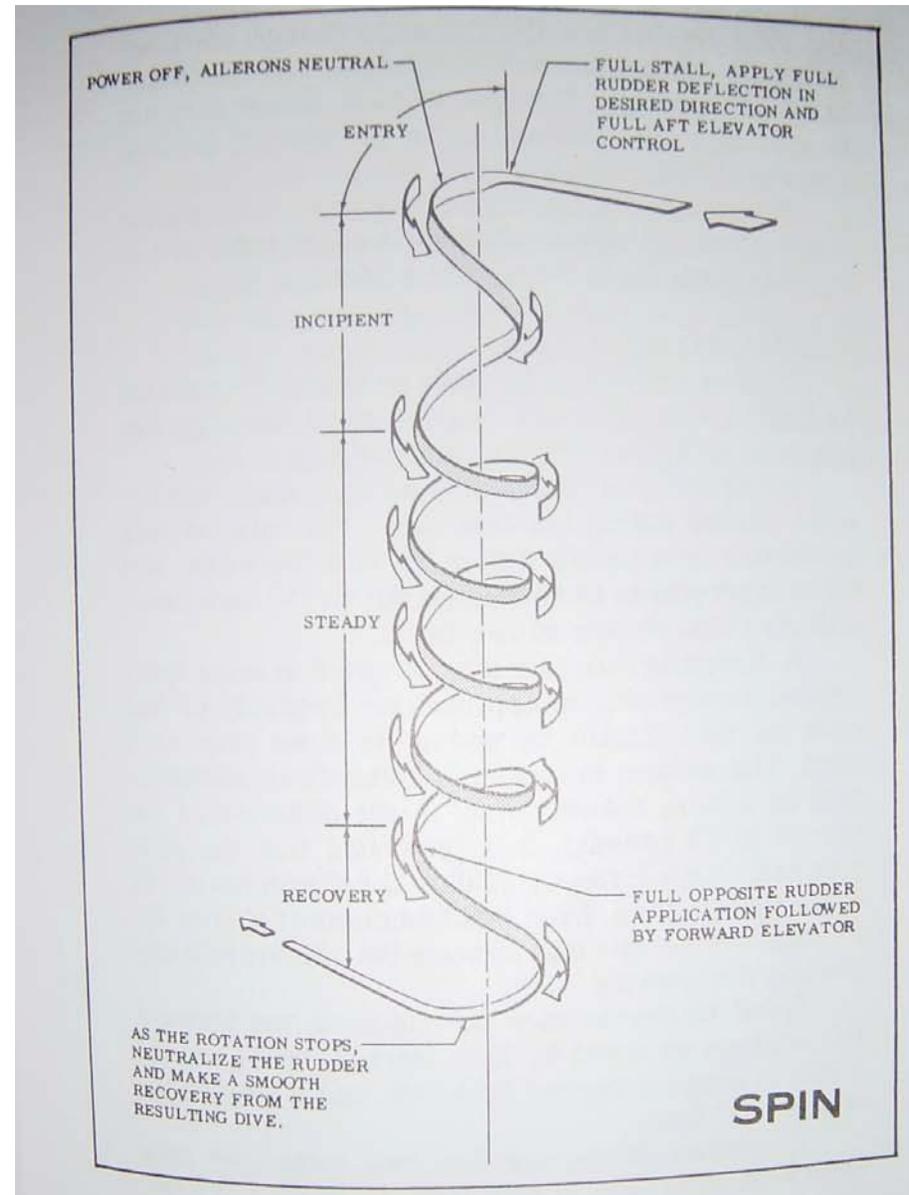
- Spins and their general characteristics
- Accident statistics and scenarios
- Some videos of spins in C172 N73857

Characteristics of the spin

- The spin is a sustained stall where angles of attack range up to 90 degrees. (Rectangular wings usually stall around 18 degrees.)
- Asymmetric lift, drag on the wings induces a rolling and yawing motion.
- Aircraft travels down along a corkscrew path.

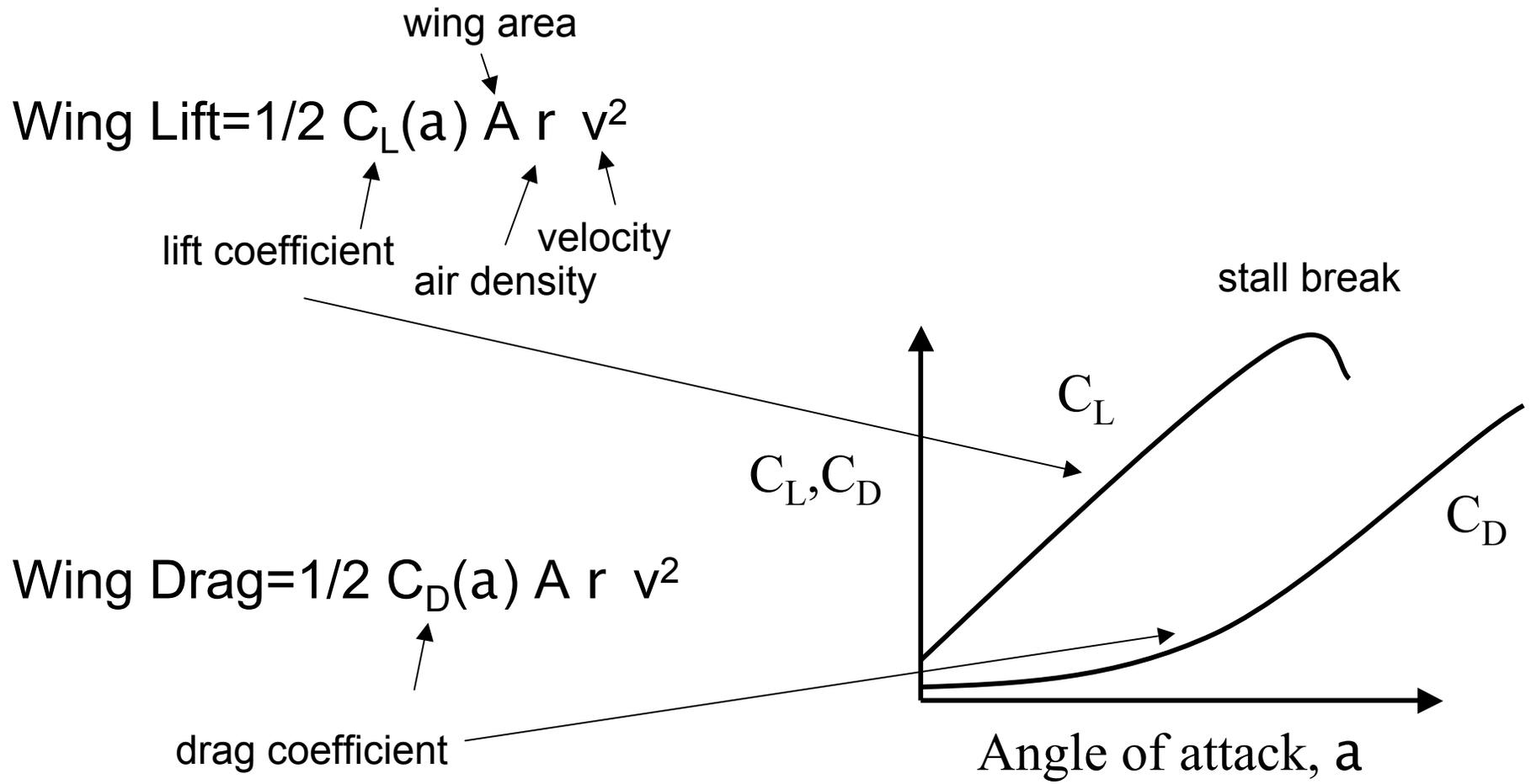
Watch an RV-8 spin:

<http://www.youtube.com/watch?v=y1Ck12HOJqI>



Reproduced from "Spin characteristics of Cessna models 150, A150, 152, A152, 172, R172, and 177"

Wing lift and drag forces vary with the angle of attack

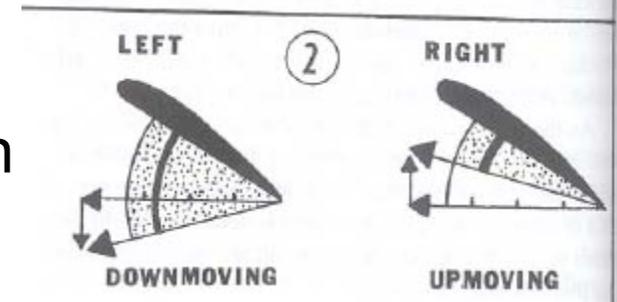


Far from the stall, airplanes exhibit roll stability.

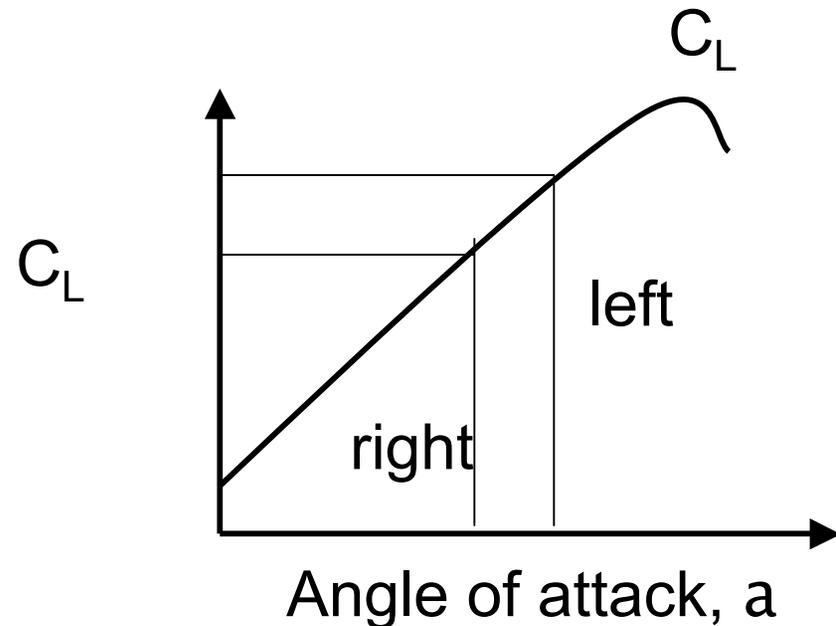
Suppose left aileron is applied to establish a left roll and aileron is quickly neutralized.

Reproduced from Kershner, "Flight instructor's manual"

Left wing has higher angle of attack in the roll.



Left wing has more lift, stopping the roll.

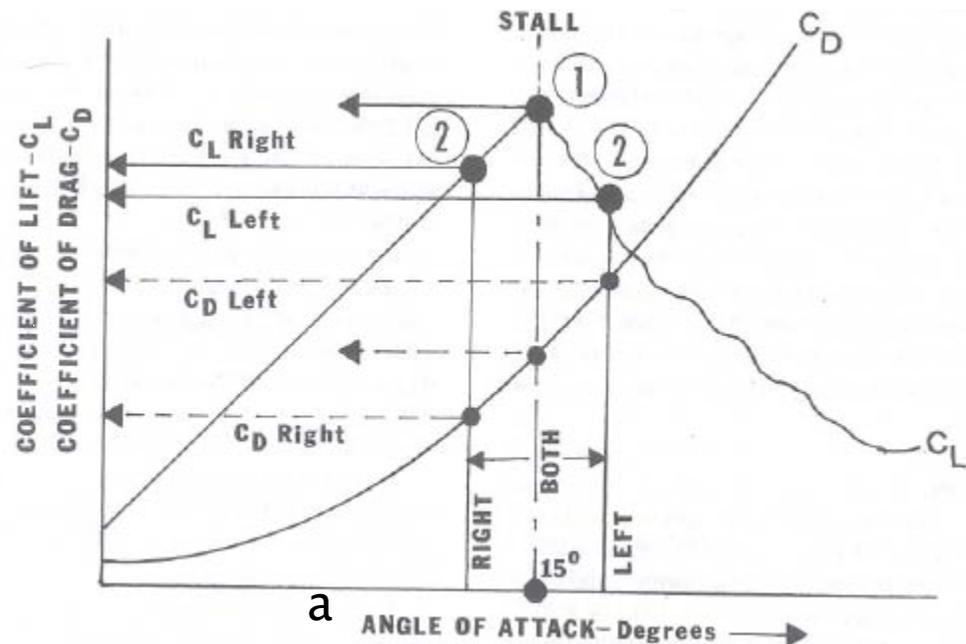
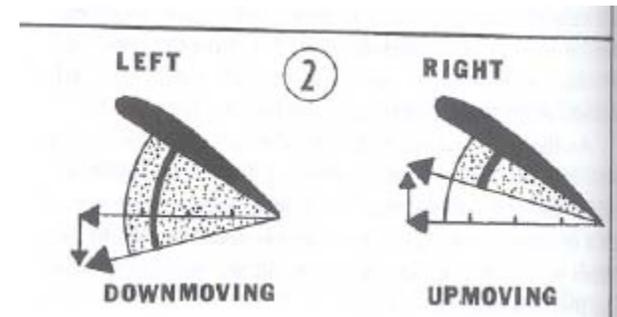


At and beyond the stall, a roll instability can develop leading to a spin

Suppose left aileron is applied to establish a left roll and aileron is quickly neutralized.

Left wing has higher angle of attack in the roll.

Roll is NOT stopped in this case. A spontaneous sustained rolling and yawing motion results from asymmetric lift



Reproduced from Kershner, "Flight instructor's manual"

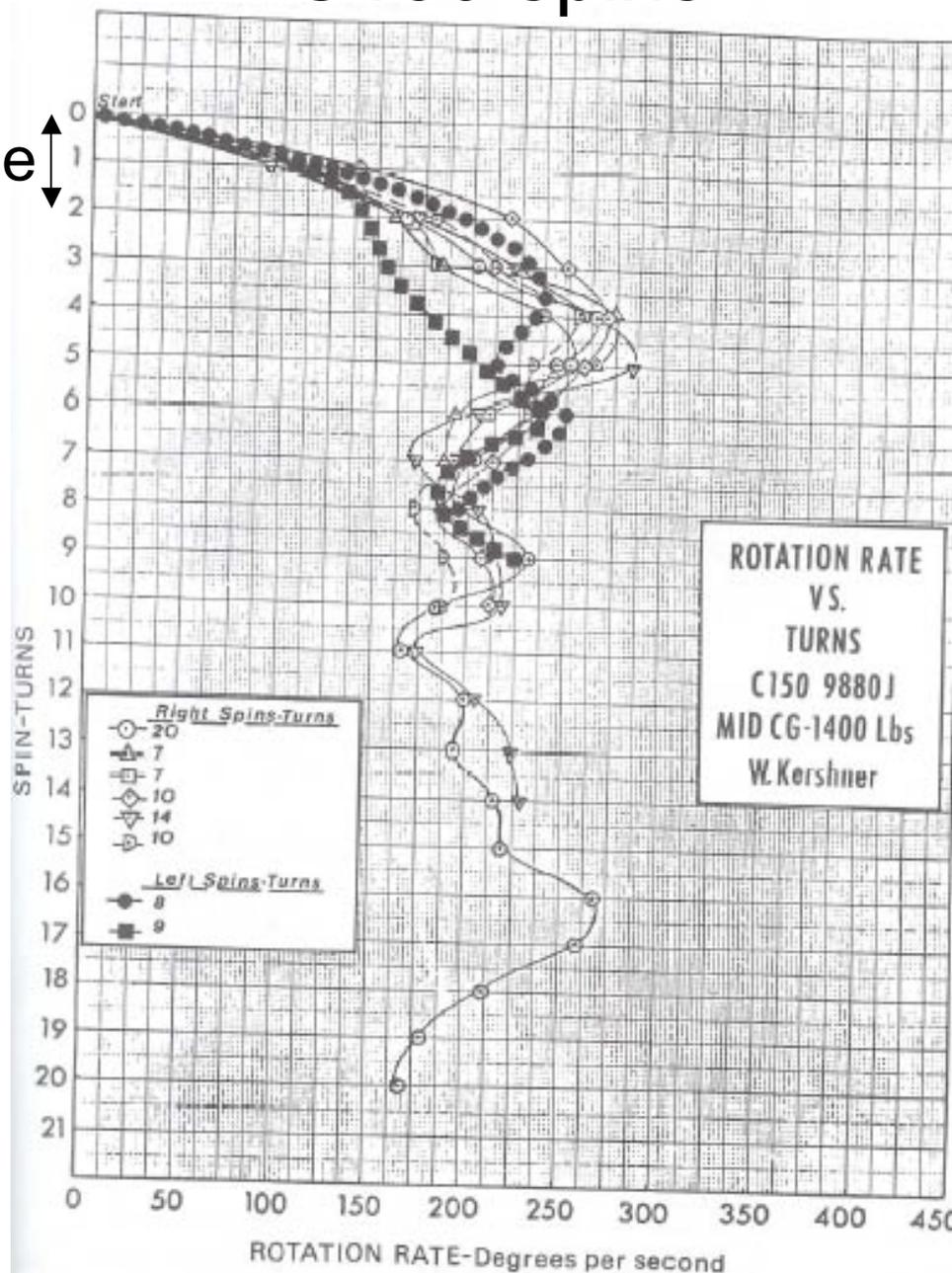
C150 spins

Approximate pitch angle

Incipient phase

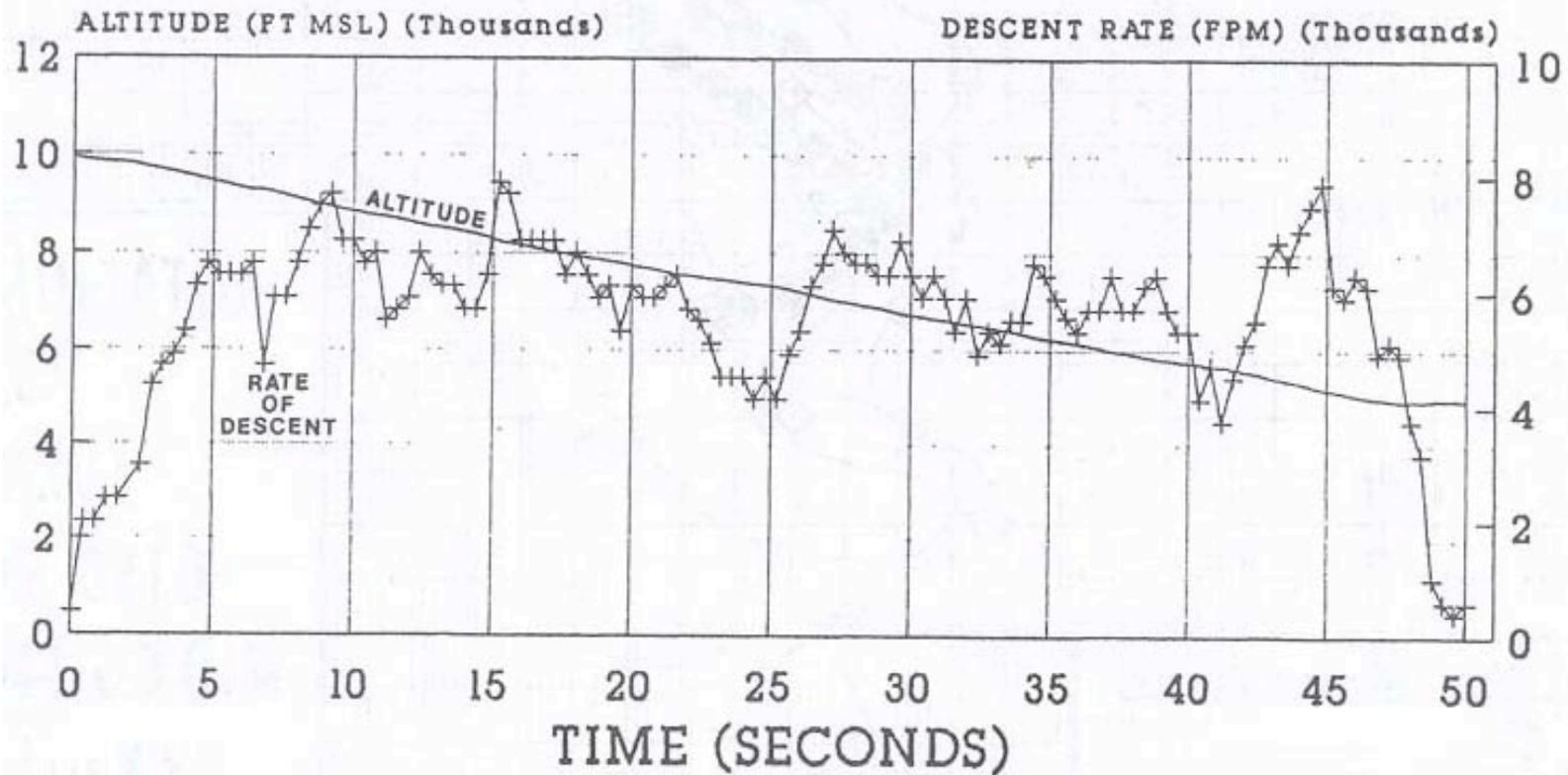
Spin roll rate is significantly higher than aileron roll rate

Angles of attack well deep into stall regime are achieved



Reproduced from Kershner, "Basic Aerobatic Manual"

Descent rates of up to 8000 fpm (80 kts) achieved for C150 Aerobat.



Reproduced from Kershner, "Flight instructor's manual"

Spins are the 800 pound gorilla in the corner of the flight school lobby

Spins have some potentially useful characteristics, including high vertical descent rates (8000 fpm!) at low speeds. But drawbacks include:

- Spins may be unrecoverable
- Potential disorientation from high roll rate
- Counterintuitive recovery procedure required (apply down elevator despite low pitch attitude)
- Significant variations in spin characteristics with aircraft type and even serial number within same type, CG location, fuel configuration, etc.

Spin Recovery

- Every aircraft is different: Use the procedure given in the POH
- Generally: **PARE**
 - **P**ower to idle
 - **A**ilerons neutral
 - Raise flaps if lowered
 - **R**udder in opposite direction of spin
 - **E**levator quickly forward when rotation slows (0-1.5 turns typically, slower for flatter spin)
- Pull out of the dive (2-3 g's) before V_{NE} exceeded

Aileron deflection may help or hinder recovery, depending on aircraft

- Pro-spin deflection may increase the spin roll rate (C152, C172)
- Anti-spin deflection may exacerbate the spin through adverse yaw
 - Adverse yaw makes the aircraft yaw right when left aileron is applied
 - This issue is generally more significant for swept-wing aircraft

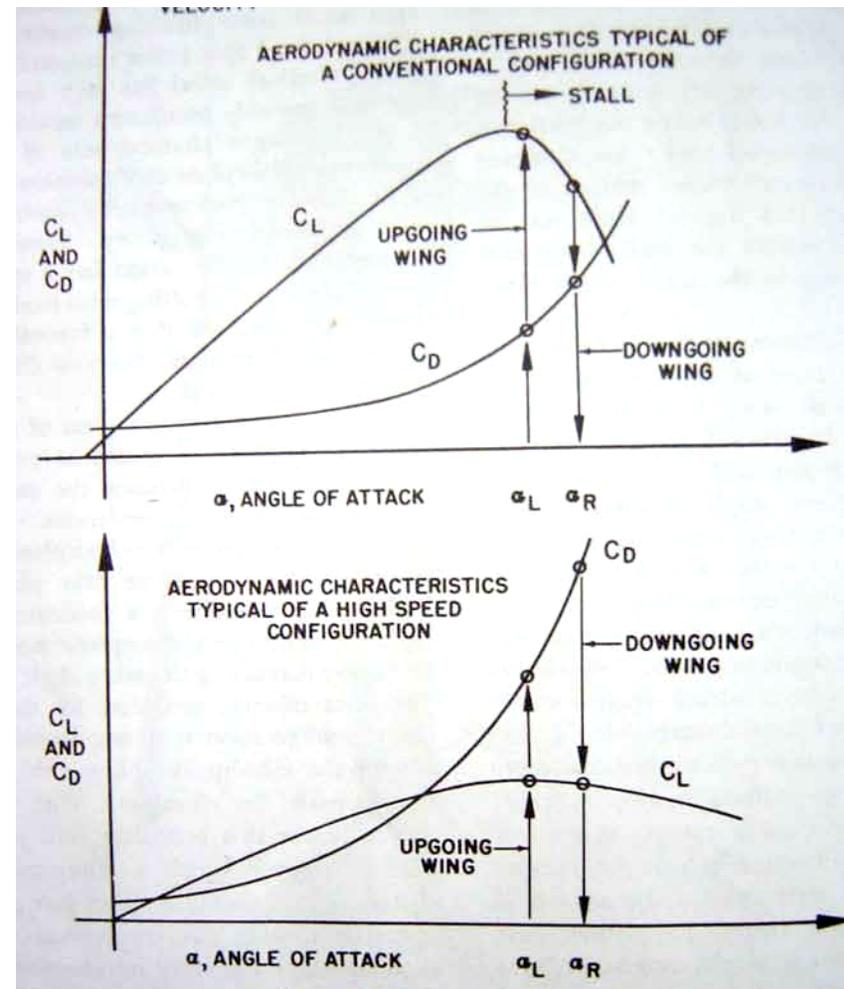
Use the POH procedure, or neutralize if uncertain.

Adverse yaw is a more significant issue for swept wing aircraft

Low-speed controllability was an early challenge for century series fighters in 1950s



Pilots enhanced low-speed controllability of F-100 by lodging elbows in side of cockpit to neutralize ailerons

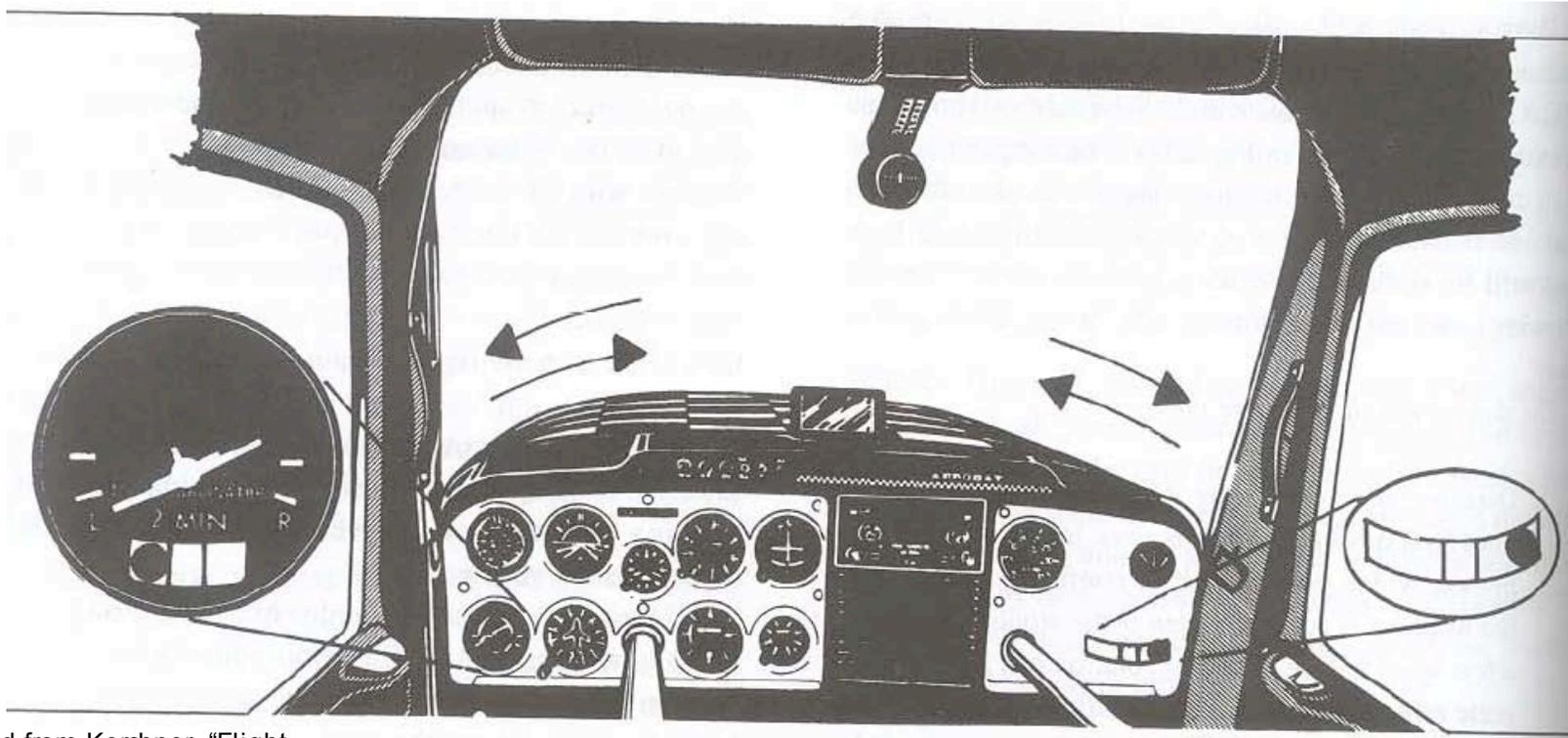


From Aerodynamics for Naval Aviators

Modern certification requirements include “normal” controllability in slow flight, i.e. left ailerons make plane turn left

Which rudder to step on?

Ball indication depends on panel location: Do not “step on the ball.”



Reproduced from Kershner, “Flight instructor’s manual”

Rate of turn indicator shows roll direction

Step on the high wing of the RT indicator to recover

Elevator forward

- Don't necessarily wait until rotation stops
 - Rudder effectiveness may be insufficient to stop rotation, (e.g. C152)
- Roll rate may *increase* before spin exited
 - The steepest, fastest spin modes are closest to the stall break
 - Technique may be important here
 - May have to push to the stop and wait a turn or two for developed spins
 - Negative g's may induce transition to inverted spin

Watch a 60 turn spin in a C152:

<http://www.youtube.com/watch?v=laPkIVfCdAI>

FAA spin certification requirements (23.231)

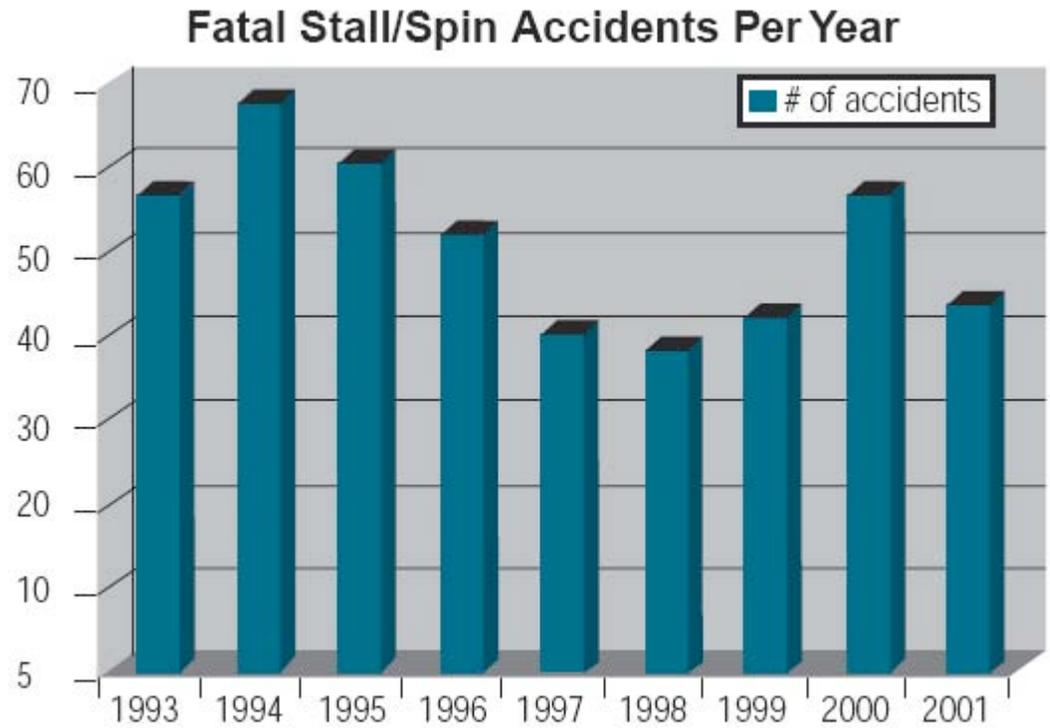
- Normal category
 - Demonstration of 1 turn or 3 sec (whichever longer) with recovery accomplished within 1 turn of anti-spin controls
 - Unrecoverable spins during this period should be impossible
 - There could be an unrecoverable flat spin lurking beyond 1 turn or 3 sec (incipient phase)!
- Utility category
 - Same as normal, but can be certified for spins if aerobatic category spin requirements demonstrated
- Aerobatic category
 - Demonstration of 6 turns (or more) with recovery accomplished within 1.5 turns of anti-spin controls
- Twins
 - No spin certification requirements

Bottom line: consult POH for spin certification

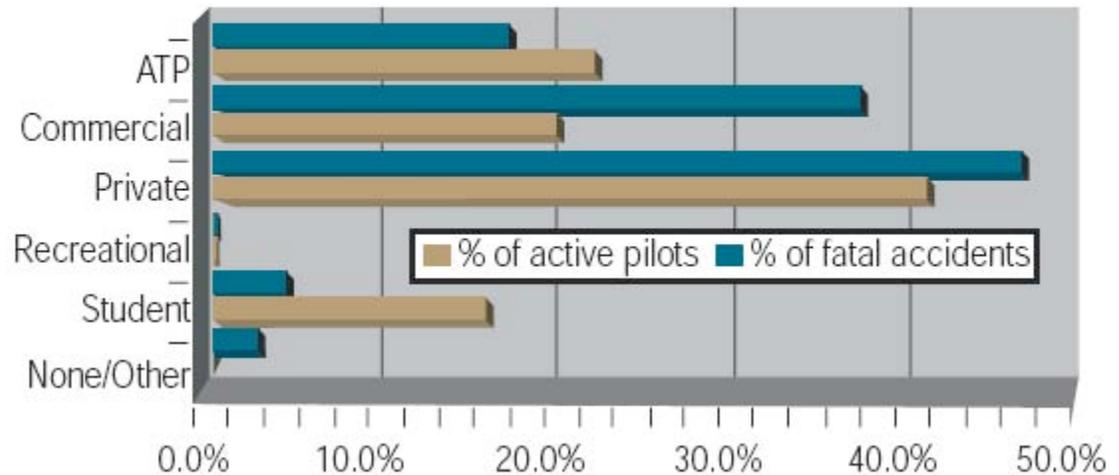
Factors governing ease of recovery

- Aircraft design: fuselage cross section, tail type, etc.
- Length of time in spin: longer is slower to recover
- Flatness: flatter is slower to recover
- CG of aircraft: rear CG gives slower recovery (shorter lever arm for rudder and elevator)
- Additional factors:
 - Wing tank fuel imbalance can inhibit recovery
 - Mass distributed far from the CG (larger moments of inertia) can inhibit recovery, e.g. twins

Accident Statistics

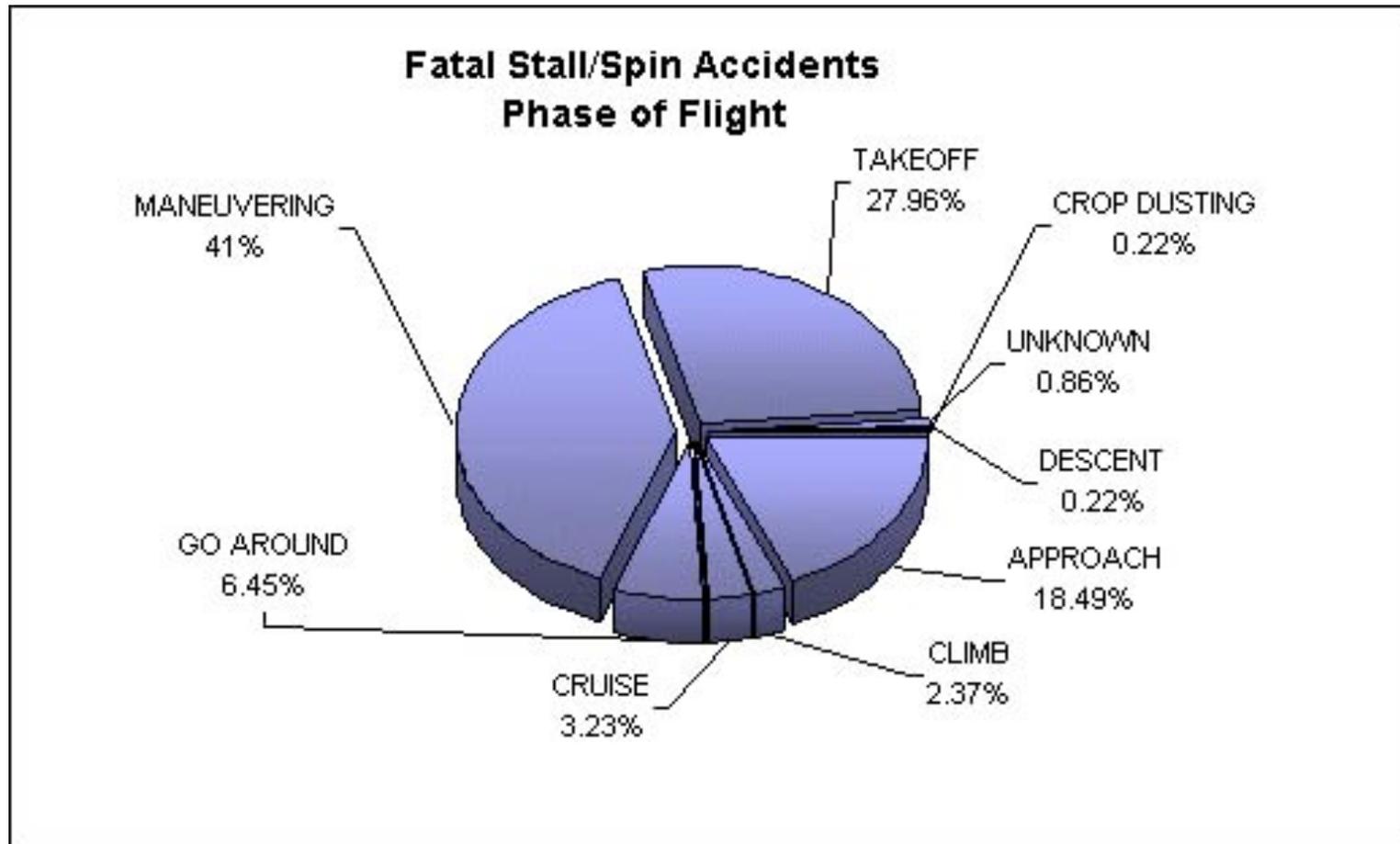


Fatal Stall/Spin Accidents
Certificate Level



Source: AOPA Air Safety Foundation

Source: AOPA Air Safety Foundation



Details in most NTSB stall/spin accident reports are sparse.

Pitts spin accident summary: CG location affects spin characteristics

NTSB Number: MIA01FA041

Pitts day VMC maneuvering accident summary

NTSB narrative: An FAA contract tower controller at the Hollywood North Perry Airport stated that at 0950 he received a radio communications transmission saying, "mayday mayday mayday pitts 260DB in an unrecoverable flat spin at 3,500 feet." The aircraft was discovered in a partially inverted, near vertical pitch attitude, in an area of heavy brush, sawgrass, and tall trees in the Everglades, in about 3 to 4 feet of water. The aircraft had incurred substantial damage, and the pilot/owner and PIC were found outside the aircraft, with both having sustained fatal injuries....

Examination of N260DBs weight and balance revealed that the aircraft's weight and center of gravity limits had been exceeded. The aircraft weighed 1,745 lbs, and its estimated CG was about **90.87**. According to the airplane flight manual, the airplane's weight limit in the aerobatic category is 1,625 lbs. Its forward CG limit is **89.58** at 1,625 lbs, and its most rearward CG limit is **90.50** at 1,625 lbs.

NTSB probable cause: An inflight loss of control by both pilots while maneuvering, which resulted in an inverted flat spin, an uncontrolled descent, and an impact with terrain/water. A factor contributing to the accident was the failure of both pilots to ensure that the aircraft's weight and center of gravity limitations had not been exceeded.

The flat spin

Flatter spin=higher angle of attack=more difficult to recover (flight controls are generally not designed to function at extreme angles of attack)

The flatness of a spin depends on aircraft design, CG location, control application, number of turns

Watch an F-14 and Extra 300 flat spin:

<http://www.youtube.com/watch?v=9SUWviXpT64>

<http://www.youtube.com/watch?v=EJp6WAEVlwY>

Snap roll: Higher g cousin of the spin

Snap rolls are aerodynamically similar to intentional spins but occur at higher speeds, i.e. the stall is accelerated.

$$\text{Wing Lift} = \frac{1}{2} C_L(a) A \rho v^2$$

Diagram illustrating the components of the lift equation:

- Wing area (points to A)
- lift coefficient (points to $C_L(a)$)
- air density (points to ρ)
- velocity (points to v^2)

The $C_L(a)$ situation is identical to a spin, but faster speed provides larger asymmetric lift and faster rotation rates that exceed the roll rate of full aileron deflection.

Watch a Pitts do a snap roll:

<http://www.youtube.com/watch?v=weaVw9aXhdk>

Spinning C172 N73857

POH excerpt:

“Up to 2 turns, application of recovery controls will produce prompt recoveries (within 1/4 turn). During extended spins of 2-3 turns or more, the spin will tend to change to a spiral....”

POH recovery procedure (sound familiar?):

- 1) Throttle idle and ailerons neutral
- 2) Apply and hold opposite rudder
- 3) Just after rudder reaches the stop, move the control wheel briskly forward far enough to break the stall
- 4) Hold these control inputs until rotation stops
- 5) Smoothly recover from dive

POH includes some tips for getting into the spin.

<http://www.youtube.com/watch?v=Gg8CINTvOMc>

<http://www.youtube.com/watch?v=eUS98dFnrAs>

<http://www.youtube.com/watch?v=XncKKQB3674>

Conditions for the videos: Gross weight approximately 2000 lbs with nearly full fuel. Nothing in baggage compartment or rear seats.

An unscientific perusal of C172 N73857 spin characteristics

- Hard to spin without power, left or right
- Tendency to spin is very sensitive to timing of control inputs and rate of approach to stall
- A spiral develops after a few seconds in power off spin, about 800' lost
- Forward elevator movement of a few inches will break the power off spin after $\frac{1}{2}$ turn
- Burst of power at stall helps maintain spin, recovery nearly immediate upon anti-spin control application after 1 turn
- Ball is unreliable in spin, TC is good, AI seems to function ok for power off spins

Summary

- For spin recovery, consult POH
- Otherwise **PARE**
 - **P**ower to idle
 - **A**ilerons neutral
 - **R**udder in opposite direction of spin
 - **E**levator quickly forward
- Forward elevator alone may be sufficient in early phase, like a normal stall recovery
- Consider doing spins with a CFI