Wake Turbulence -- An Invisible Enemy

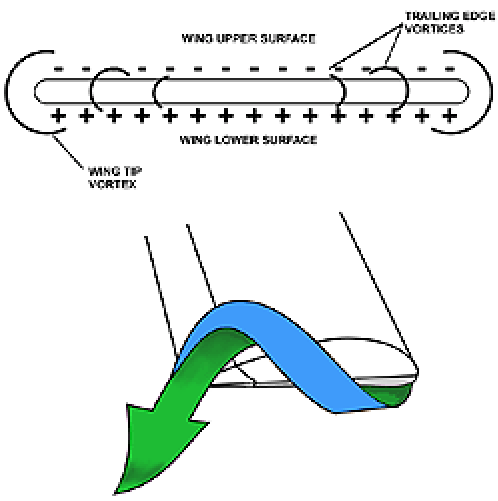
Know Your Enemy

First of all, let's take a look at what wake turbulence is -- and what it isn't. Wake turbulence -- more correctly called wingtip vortices -- is the inevitable product of lift. Remember back in the days of flight training and steep turns when your instructor told you that the "bump" you experienced at the 360° point in the turn came when you crossed your own wake? That bump was used to judge the quality of the maneuver, yet so much more could have been taught at that point.

The wingtip vortices produced by all aircraft were, in the early days of aviation, ascribed to "prop wash" -- or later to "jet wash" -- and were erroneously thought to be the result of the propeller turning through the air or the blast from a jet engine. After all, when you stand behind an airplane on the ramp, you can feel that strong wind, can't you? In the late 1960s NASA and the FAA both studied the phenomenon in some detail and discovered the twin tornadoes trailing behind any airfoil producing lift.

All airfoils produce a wake when they are producing lift. The higher-pressure air under the wing flows around the wingtip and tries to displace the lower-pressure -- and consequently lower-energy -- air on the top of the wing. The greater the pressure differential between the top and bottom of the wing, the stronger the flow around the wingtip. This airflow from the bottom of the wing tends to disturb the airflow on the top of the wing -- that's part of the increase in induced drag you notice with increased lift!

The air curling up around the wing tip forms a horizontal tornado that trails behind the airplane and tends to sink somewhat below the producing aircraft's flight path -- if that aircraft is in level flight. The vortices produced during a descent are somewhat less predictable. The vortex produced by the left wing rotates in a clockwise direction *when seen from behind.* The one from the right rotates counterclockwise. Larger airplanes produce stronger vortices because the wings produce more lift to support the weight of the airplane. The vortices settle behind the aircraft to an altitude about 1,000 below the aircraft's flight path, where they tend to remain.



A wing produces a pressure differential between the top and bottom surfaces. This pressure differential causes high-pressure air from the bottom of the wing to flow over the top of the wing and then to swirl downward creating wing tip vortices.

All the Old Rules

Let's review all the rules for dealing with wake vortices before we find out why some of them don't work. We've been taught since private pilot ground school to keep the following in mind when operating around larger aircraft:

- When taking off behind a larger aircraft, lift off before the larger aircraft's liftoff point and climb above its climb path.
- When landing behind a larger aircraft, touch down past its touchdown point.
- Vortices will stay on the runway longer in light or calm winds.
- In light crosswinds, the upwind vortex will tend to drift onto and remain on the runway.
- Vortices from a large aircraft landing on a parallel runway can be blown onto your runway by a strong crosswind.
- When flying or crossing behind a larger aircraft, maintain your flight path above the large aircraft's path.
- When approaching behind a larger aircraft on an ILS, stay at or above the glideslope to avoid wake encounters.

We've all been taught that if we follow these suggestions we will be safe from wake turbulence encounters. That must be true since we rarely read of a wake vortex encounter that ends in a crash or aircraft damage. More likely we've just been lucky.

Some Wake Encounters

An accident that may have been precipitated by a wake vortex encounter was the crash of American 587 on departure from JFK Airport in New York. It is believed that rapid rudder pedal movements made in an attempt to recover from an encounter with the wake of a 747 approximately one and one half miles ahead caused terminal stress on the vertical stabilizer, leading to its separation from the aircraft. Although it may be true that this crash was not solely the result of a wake turbulence encounter, it was a precipitating factor.

A US Airways crash near Pittsburgh, Penn., in 1994 was attributed to rudder problems on certain models of Boeing 737 aircraft, but may have been the result of rudder movements made in an attempt to recover from a wake vortex encounter.

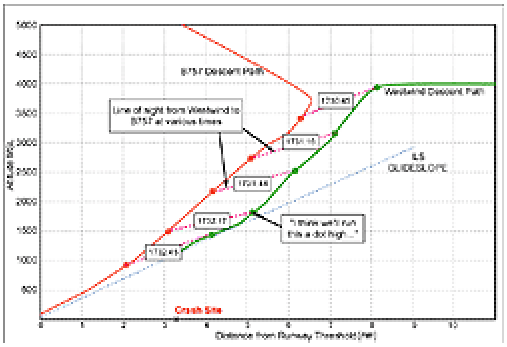
A wake turbulence encounter that perhaps has more relevance to smaller aircraft was one that occurred in December 1993 at John Wayne Airport in Orange County, Calif. A Westwind was following a Boeing 757 on approach to Runway 19R at Santa Ana in VFR weather. The Westwind crew was *never* given a wake turbulence warning, *and* they were never told the type of aircraft they were following. The CVR contains a statement from the captain to the first officer "I think we'll run this a dot high ..." The captain was aware of the danger of wake vortices (although he was not told that the preceding aircraft was a B757) and was acting appropriately, according to what we've all been taught. The Westwind crashed in uncontrolled flight three miles short of the runway.

What happened? The weather was VFR. The Westwind captain was a highly experienced pilot and he was aware of the danger. Voice tapes and radar traces show that he had the preceding aircraft in sight. What went wrong?

What the Pilot Didn't Know

The pilot operated according to his training and he was a well-trained pilot. He not only attended FlightSafety, he had at one time been a FlightSafety instructor and program manager. He flew the approach one dot high on the glideslope. He expected the wake of the preceding aircraft to be below him. Why wasn't that enough to protect his flight? Why? Because the wake of the B757 ahead of him was not below him as he expected. He did not know that ATC had descended the B757 through his intended flight path. The two flights were on separate ATC frequencies until the B757 was aligned on the localizer in front of the Westwind. The Boeing was pointed out to the Westwind but every time the Westwind captain saw the B757, he saw the aircraft as below his flight path. He had no way of knowing that the B757 had executed a steep descending turn to final that took it through the ILS glideslope that he was so careful to stay above.

He also didn't know that the preceding aircraft was a B757. This particular Boeing has a far nastier wake than would be expected. In fact, when wake turbulence testing was done on B757s by flying them by a tower equipped with sensors, the B757 was the only aircraft tested whose wake tore the sensors from the tower. The FAA never told us this. They have since reclassified the B757 and put it in a category by itself for wake turbulence separation purposes.

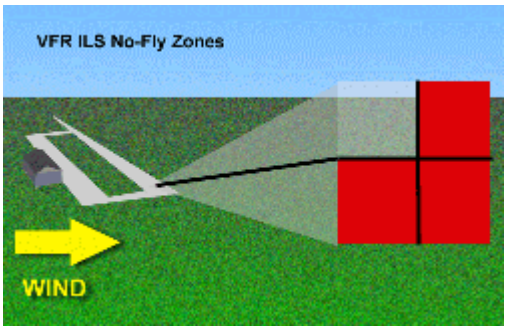


The descent paths of the B757 and the Westwind are shown here. The times shown in the boxes between the profiles illustrate that, at all points in time, the B757 appeared to be lower when viewed from the Westwind -- and in fact it was. The crucial fact that the Westwind pilot never knew was that, at all times, the B757's actual flight path was above the Westwind's. Even flying the glideslope a dot high didn't help in this instance. The Westwind flew into the B757's wake at about 1160 feet and crashed a little more than three miles from the runway.

What's a Pilot to Do?

So what in the world are we to do to avoid these deadly tornadoes? It's apparent that the old rules aren't enough to keep us safe. The Westwind pilot followed them all and came to grief. The old rules are a good start, but until large aircraft are required to use colored smoke streamers from their wingtips to make the vortices visible, we'll never be sure exactly where they are. There are some things you can do.

- Don't fly on the localizer centerline in VFR conditions. You may have noticed that these accidents seem to happen in VFR weather. When the clouds are on the deck, ATC vectors all aircraft so that they can intercept the glideslope from below. (However, that is a limitation imposed by older autopilot systems -- it may change.) When it's VFR, aircraft may have descended to the glideslope from above. If you can't use the glideslope to gauge where the turbulence may be, you're left with only the localizer. Since the larger jets are more than likely going to be on the centerline, don't fly there. Offset your flight path to the upwind side so that any wake will be moving away from you.



If you plan to follow an ILS in VMC weather, make sure you fly above the glide slope and on the upwind side of the localizer path.

- Think twice before you accept a visual approach behind a large aircraft. When you accept the visual, ATC is no longer responsible for wake separation -- you are -- and as we've seen, you may not be able to tell just where the wake may be.
- On takeoff, turn off the runway centerline as soon as safely possible. You probably cannot out-climb the new-generation jets, and you won't want to fly into their wake.
- If you are faced with crossing the flight path of a large airplane while en route, it's best to cross at or above the altitude of the jet and at least two miles behind it.
- Find a training center providing upset training. This is one of those areas where simulator training won't really cut it. True, you can learn the basic procedures in a simulator, but there's absolutely no way to learn how it feels to be hanging from the seat belts other than hanging from the seat belts.
- If upset training is not available to you, get a couple of hours of dual instruction with a good aerobatic instructor in an aerobatic airplane. At least you can experience being upside down, and a good instructor will be able to show you how to recover from unusual attitudes that your primary instructor never dreamed of. It has been said that there is no such thing as an unusual attitude for aerobatic pilots, and if you've ever watched the likes of Patty Wagstaff, you'll believe that to be true.

Not Just Behind the Heavies

When all is said and done, however, the best defenses against a wake turbulence encounter are awareness and alertness. My own most scary encounter was not even the result of flying behind a jet. I had cut my teeth flying freight in and out of Chicago O'Hare and had never had a nasty wake encounter there, although the potential certainly existed. My wake encounter happened as I departed FWA one beautiful summer evening in a Piper Navajo Chieftain with five businessmen settled in the seats looking forward to an evening in Indianapolis. The wind was 3, gusting to 4, and an Air Wisconsin DeHaviland Dash 7 had just departed the runway ahead of me. He was on a downwind departure and was already behind me when the tower cleared us to go. I pushed the power up and started down the runway. I rotated and begin my climb while reaching for the gear handle. Just as I retracted the gear the Navajo sharply banked 80 degrees to the right and the nose came up. One moment I was flying, the next I was sure I was going to make an airplane-shaped hole in the grass next to the runway. Needless to say, that didn't happen and I got the airplane flying again, but my experience illustrates how complacency can sneak up and bite.

Looking back on the incident, it is clear that all the warning signs were there. The preceding aircraft, although not a jet, was a STOL aircraft that generated a lot of lift at fairly slow speeds. The wind was almost calm. I was at the end of a long day and the last thing on my mind was a possible wake vortex encounter. Bingo! I flew right into it. Later my co-pilot asked me to tell him what procedures I had used and the order in which I had applied them to recover from the upset. The best I could tell him was that I just made the airplane fly again. If you have to think out the procedure, you'll run out of time. The procedure has to be almost instinctive, but if you haven't had any aerobatic training, your instinctive procedures may be the exact opposite of what is required.

Keep your eyes open and be aware of the situations where wake turbulence may be encountered and take measures to avoid it. It's certainly easier to avoid it in the first place than try to recover once you're in the teeth of it. It amazes me that there are not more wake encounters -- I think we've been just plain lucky!