THE INVISIBLE DANGER : WAKE TURBULENCE

Original idea from Airliner

Wake turbulence has been known since the early days of aviation. The introduction of wide-body aircraft and the wake turbulence associated with their heavy weights, an increase of air traffic and safety concerns, prompted industry and government interest. Much investigation and analysis was done by Boeing and other agencies in the 1960s and 1970s. It was during this time when some ground rules, or to be more precise, air rules were established so that this usually invisible hazard could be avoided. What are the wake turbulence issues of the 1990s? To answer that question we need to review some of the things we already know about wake turbulence…

WAKE TURBULENCE STUDIES

First statement : wake turbulence is generated during flight when the wing develops lift. A pair of counter-rotating trailing vortices emanate from the wings, and are usually invisible. This region of rotating air behind the airplane is where wake turbulence occurs. Boeing interest in the effects of wake turbulence dates to the mid 1960s. During the development of the 747, Boeing worked with the FAA and the National Aeronautics and Space Administration (NASA) to evaluate the hazards of wake turbulence and define separation standards. Boeing continued work on wake turbulence issues during the '70s, '80s and into the '90s by conducting research and development and by supporting NASA and FAA programs.

Analytical studies of wake turbulence and its effect on following aircraft began at Boeing in 1969 and resulted in a series of flight tests conducted in 1969 and 1970 in cooperation with NASA and the FAA. These tests were designed to provide a direct comparison between the 747 and an airplane representative of the existing jet fleet, the 707-320B. NASA and the FAA conducted additional experimental studies to expand the understanding of wake turbulence. This work validated our understanding of the initial strength of the vortices and the descent path of the wake.

This work provided the FAA a basis for establishing separation standards as a means for trailing airplanes to avoid the wake turbulence of the preceding airplane. Now more wake turbulence research is being started to study traffic capacity at major airports as well as improve airplane safety.

WAKE TURBULENCE FORMATION, MOVEMENT AND DISSIPATION

The forces that create trailing vortices also create the forces that lift the airplane. High-pressure air from the lower surface of the wing rushes around the wing tip to

the lower-pressure region above the wing. A pair of counter-rotating vortices are thus shed from the wing with the right wing vortex rotating counterclockwise and the left wing vortex rotating clockwise, as shown in Figure 1.

The initial strength of the turbulence is predominantly determined by the weight, speed and wingspan of the aircraft.

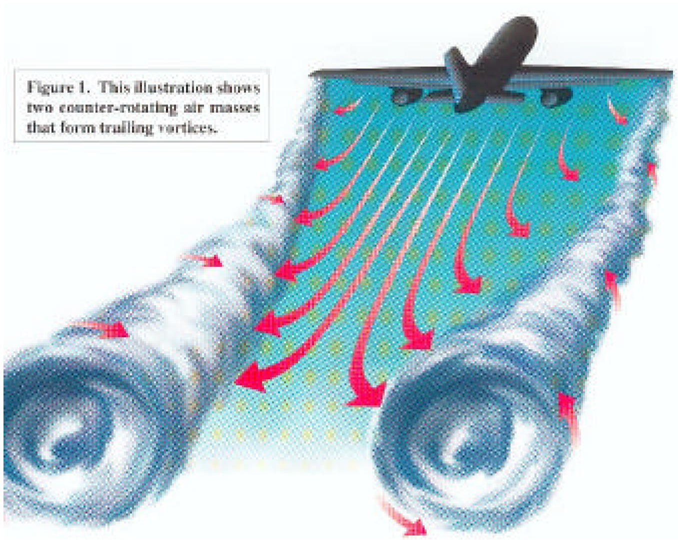


Figure 1. This illustration shows two counter-rotating air masses that form trailing vortices.

Research has shown that for a typical jet transport airplane, the wake descends behind the generating airplane at approximately 300 to 500 feet per minute for about 30 seconds. As seen in Figure 2, the descent rate decreases and eventually approaches zero at between 500 and 900 feet below the flight path.

On takeoff and approach, the wake descends below the flight path until it enters ground effect where the two vortices stop their downward descent and move laterally. This behavior is illustrated in Figure 3. Typically, the wake's descent will be arrested at a height above the ground equal to approximately one half the length of the airplane wingspan. Below this height, the wake does not form into concentrated vortices and the turbulence in the wake is relatively weak. Thus, the severity is reduced in the touchdown areas shown in Figure 3.

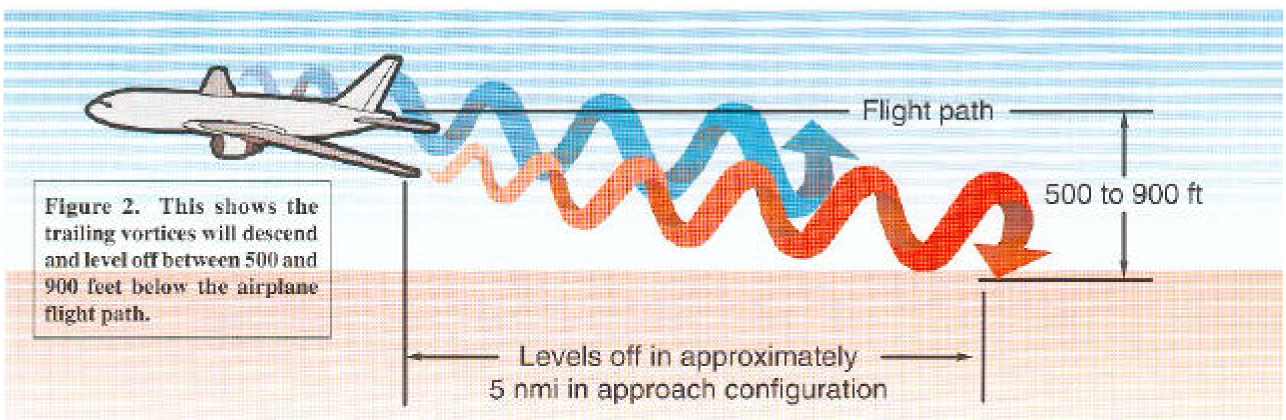


Figure 2. This shows the trailing vortices will descend and level off between 500 and 900 feet below the airplane flight path.

Prevailing surface winds will also influence the direction the vortices will move; thus, during parallel runway operations, the wake turbulence hazard must be a consideration on both runways. Additionally, under some crosswind conditions, vortices have been observed to "bounce" - that is, descend toward the ground and then later begin to rise up. For the conditions where bounce has been observed, the crosswinds are strong enough to clear the vortices from the approach corridor.

The decay process of the wake is complex and is strongly influenced by atmospheric conditions. The process is driven by :

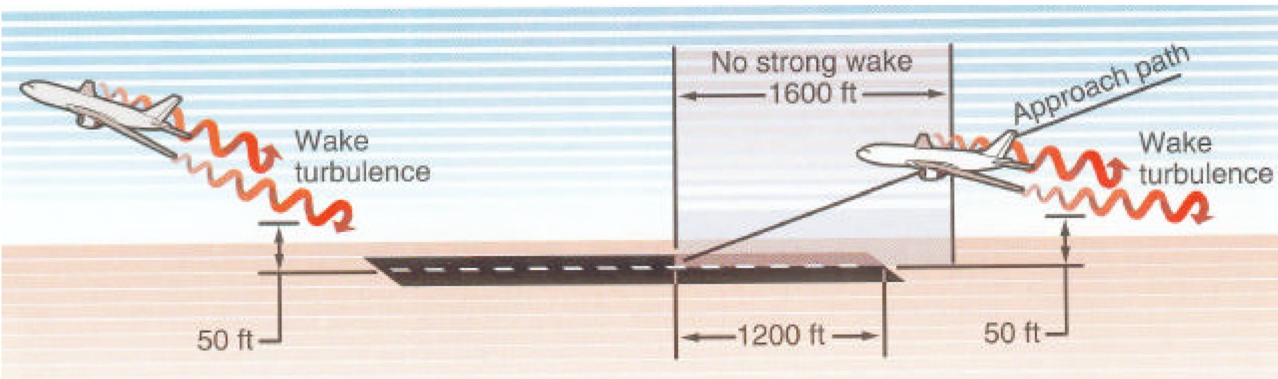
- **Atmospheric Turbulence -** Atmospheric turbulence plays a significant role in the decay of the vortex. Atmospheric turbulence imparts viscous forces on the wake. These forces extract energy from the vortex, thus reducing its strength. The heavier the turbulence, the quicker the wake decays.

- **Viscous Interactions -** The viscosity (property of a fluid to resist motion) of the atmosphere creates an upward force on the wake as it descends. This force slowly extracts energy from the vortex, thus reducing its strength.

- **Buoyancy -** An upward force acts on the vortex as a result of the air density inside being lower than the air density outside the vortex. This force also slowly extracts energy from the vortex, thus reducing its strength.

- **Vortex Instability -** A small amount of turbulence in the atmosphere can create an instability in the vortex pair that causes the vortices to link. When the vortices link, the strength of the pair decays rapidly.

In very calm atmospheric conditions, it is possible for the wake to persist, although much weaker in strength, for distances in excess of the wake turbulence airplane separation distances established by the FAA. In turbulent atmospheric conditions, the wake may persist for only a fraction of the wake turbulence separation distances.



SUMMARY

All pilots should review wake turbulence avoidance procedures such as those listed in the US Airman's Information Manual. Additionally, pilots must maintain good situational awareness when they take over visually during the landing phase. Further scientific investigation of wake turbulence and development of detection and prediction systems is under way.

This, it is hoped, will allow integration of wake turbulence information into air traffic control procedures and safely permit tailored airplane separations and increased airport capacities.

Meanwhile, pilots and air traffic controllers must work together to avoid hazards associated with wake turbulence.

The FAA is distributing the Turbulence Training Aid video. For of the Training Aid and please contact :

National Technical
Information Service
5285 Fort Royal Road
Springfield, Virginia 22161
USA

HOW TO AVOID WAKE TURBULENCE

Avoiding wake turbulence is not always easy. Dissimilar airplane speeds and sizes, converging flight paths, and unknown or "pop up" traffic are some of the situations that pilots must resolve in order to maintain safe distances. It doesn't take much of a visual error or a small increase in cockpit workload to end up with insufficient separation on final approach.

Maintaining proper separation is the best approach to avoiding wake turbulence. We can't emphasize that strongly enough. A pilot who ends up with insufficient separation on final approach should still, as advised in the Airman's Information Manual, fly above the flight path of the preceding airplane and land beyond its touchdown point.

These tactics, however, may be easier to discuss than to actually use. If there is an ILS available, the normal technique is for the trailing pilot to fly high on the glide slope. That's a good idea, but it assumes the leader airplane is flying on the glide slope. This is not always a valid assumption. In fact, the pilot of the *leader airplane* may also be attempting to avoid wake turbulence and is above the normal glide slope.

For similar reasons, noise abatement procedures and fuel conservation approaches - requiring higher-than-normal flight paths during takeoff or landing - may involve the use of wake turbulence avoidance tactics.

Attempting to liftoff at a point before and fly above the takeoff flight path, or turning off course from the previous airplane, isn't always completely foolproof, either. And there may be hazards at those airports with closely spaced parallel runways; remember, as indicated earlier, vortices can linger on the ground, move, and usually cannot be seen.

Another reason for wake turbulence incidents is the growth in number and sizes of airplanes. When the initial separation standards were set, the categories consisted of a few airplanes that were grouped relatively close together. Today, the fleet consists of a wide variety of airplanes with a broad weight range. Also, bigger airplanes share busy airports with an expanded population of smaller commuter airplanes.

Avoidance is the key, so keep a safe distance and stay above the leader's flight path to avoid wake turbulence.