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Fundamentals of Flight

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- Refueling and rearming instructions, including forward arming and refueling point locations.
- Emergency medical procedures.
- Location of AMC and aviation unit commander.

SECTION V – WAKE TURBULENCE

6-107. Information on wake turbulence is placed in this chapter as aviators are likely to experience turbulent conditions while operating around other aircraft. Successful aviators understand and recognize conditions conducive to wake turbulence and take appropriate countermeasures. Larger aircraft create more turbulence and are greater hazards.

IN-FLIGHT HAZARD

6-108. Every aircraft in flight generates wake turbulence. This disturbance is caused by a pair of counter-rotating vortices trailing from the wing tips. It is possible the wake of another aircraft can impose rolling moments exceeding the control authority of the aircraft. Additionally, if encountered at close range, wake turbulence can damage the aircraft and/or cause personal injury to the occupants. It is important to imagine the location of the vortex wake generated by other aircraft and adjust the flight path accordingly.

GROUND HAZARD

6-109. Hazardous turbulence is not only encountered in the air. During ground operations and takeoff, jet engine blast (thrust stream turbulence) and rotorwash can cause damage and disturbance if encountered at close range. Exhaust velocity versus distance studies at various thrust levels have shown a need for light aircraft and helicopters to maintain an adequate separation behind large turbojet aircraft.

VORTEX GENERATION

6-110. Lift is generated by the creation of a pressure differential over the wing surfaces. This pressure differential triggers rollup of airflow aft of the wing resulting in swirling air masses trailing downstream of the wingtips (figure 6-29). After rollup is completed, the wake consists of two counter-rotating cylindrical vortices. Most of the energy is within a few feet of the center of each vortex; however pilots must avoid the region within approximately 100 feet of the vortex core.

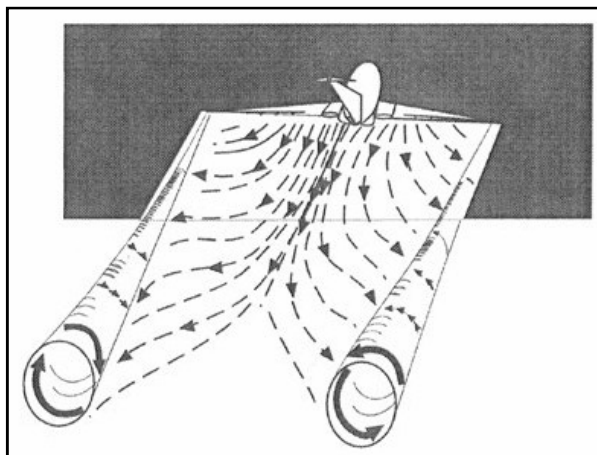


Figure 6-29. Wake vortex generation

STRENGTH

6-111. Vortex strength is governed by the weight, speed, and shape of the generating aircraft's wing. The basic factor is weight; vortex strength increases proportionately with an increase in aircraft operating weight. Peak vortex speeds up to almost 300 feet per second have been recorded. The greatest vortex strength occurs when the generating aircraft is heavy, clean, and slow.

BEHAVIOR

6-112. Trailing vortices have certain behavioral characteristics which can help aviators visualize wake location and take avoidance precautions.

- Vortices are generated from the moment an aircraft leaves the ground because trailing vortices are a by-product of wing lift. Prior to takeoff or landing, pilots should note the rotation or touchdown point of the preceding aircraft.
- Vortex circulation is outward, upward, and around the wing tips when viewed either ahead or behind the aircraft. If persistent vortex turbulence is encountered, a slight change of altitude and lateral position (preferably upwind) should provide a flight path clear of the turbulence.
- Flight tests have shown vortices from aircraft sink at a rate of up to several hundred FPM, slowing their descent and diminishing in strength with time and distance behind the generating aircraft. Atmospheric turbulence hastens breakup. Aviators should fly at or above the preceding aircraft's flight path, altering their course as necessary to avoid the area behind and below the generating aircraft.
- A crosswind decreases lateral movement of the upwind vortex and increases movement of the downwind vortex. This results in the upwind vortex remaining in the touchdown zone for a period of time and increases drift of the downwind vortex toward another runway.

INDUCED ROLL AND COUNTER CONTROL

6-113. Army aircrews should be aware of the following conditions to avoid the adverse effects of larger aircraft vortices. The available power may be insufficient to counter turbulent air near the runway environment.

INDUCED ROLL

6-114. In rare instances, a wake encounter can cause in-flight structural damage of catastrophic proportions. The most common hazard is associated with induced rolling moments which can exceed the roll control capability of the encountering aircraft. During flight tests, aircraft have been intentionally flown directly up trailing vortex cores of larger aircraft. These tests prove the capability of an aircraft to counteract the roll imposed by the wake vortex primarily depends on wing span and counter control responsiveness of the encountering aircraft.

COUNTER CONTROL

6-115. Counter control is usually effective and induced roll is minimal in cases where the encountering aircraft extends outside the affected area of the vortex. It is more difficult for aircraft smaller than the aircraft generating the vortex to counter the imposed roll induced by vortex flow. Although aviators of short span aircraft and helicopters must be especially alert to vortex encounters, the wake of larger aircraft requires the respect of all aviators.

OPERATIONAL PROBLEM AREAS

6-116. Wake turbulence encounters can be one or more jolts with varying severity depending upon direction of the encounter, weight of the generating aircraft, size of the encountering aircraft, distance from the generating aircraft, and point of vortex encounter. The probability of induced roll increases when the encountering aircraft's heading is generally aligned or parallel with the flight path of the generating aircraft.

- Avoid the area below and behind the preceding aircraft especially at low altitude where even a momentary wake encounter could be hazardous.
- Aviators must be particularly alert in calm wind conditions and maneuvering situations in the vicinity of the airfield where the vortices could—
 - Remain in touchdown area.
 - Drift from aircraft operating on a nearby runway.
 - Sink into takeoff or landing path from crossing runway.
 - Sink into traffic patterns from other airport operations.
 - Sink into flight path of aircraft operating VFR.

6-117. Aviators should visualize the location of the vortex trail behind a larger aircraft/helicopter and use proper vortex avoidance procedures to achieve safe operation. Whenever possible, it is equally important aviators of a larger aircraft/helicopter plan or adjust their flight paths minimizing vortex exposure to other aircraft.

HELICOPTERS

6-118. In a slow hover taxi or stationary hover near the surface, helicopter main rotor systems generate downwash producing high velocity outwash vortices to a distance approximately three times the diameter of the rotor. When rotor downwash hits the surface, the resulting outwash vortices have behavioral characteristics similar to wing tip vortices produced by FW aircraft. However, vortex circulation is outward, upward, around, and away from the main rotor(s) in all directions. Aviators should avoid operating within three rotor diameters of any helicopter in a slow hover taxi or stationary hover. In forward flight, departing or landing helicopters produce a pair of strong, high speed trailing vortices similar to wing tip vortices of larger FW aircraft. Aviators must use caution when operating or crossing behind landing and departing helicopters.

JET ENGINE EXHAUST

6-119. Engine exhaust velocities, generated by larger jet aircraft during ground operations and initial takeoff roll, dictate the desirability of lighter aircraft awaiting takeoff to hold well back of the runway edge at the taxiway hold line. It is also desirable to align the aircraft to face any possible jet engine blast effects.

6-120. The FAA has established standards for the location of runway hold lines. For example, runway intersection hold short lines are established 250 feet from the runway centerline for precision approach runways served by approach category C and D aircraft. For runways served by aircraft with wingspans over 171 feet, such as the C-5, taxiway hold lines are 280 feet from the centerline of precision approach runways. These hold line distances increase slightly with an increase in field elevation.

VORTEX AVOIDANCE TECHNIQUES

6-121. Under certain conditions, airport traffic controllers apply procedures for separating aircraft operating under instrument flight rules. The controllers also provide VFR aircraft with the position, altitude, and direction of larger aircraft followed by the phrase “caution–wake turbulence.” Whether or not a warning has been given, aviators are expected to adjust their operations and flight path(s) as necessary to avoid serious wake encounters.

6-122. The following vortex avoidance procedures are recommended:

- Landing behind a larger aircraft on the same runway. Stay at or above the larger aircraft's final approach flight path, note the touchdown point, and land beyond it.
- Landing behind and offset from a larger aircraft landing on a parallel runway that is closer than 2,500 feet. Consider possible vortex drift onto your runway, stay at or above the larger aircraft's final approach flight path, note its touchdown point, and land beyond it.
- Landing behind a larger aircraft on a crossing runway. Cross above the larger aircraft's flight path.
- Landing behind a departing larger aircraft on the same runway. Note the larger aircraft's rotation point and land well prior to rotation point.
- Landing behind a departing larger aircraft on a crossing runway. Note the larger aircraft's rotation point. If past the intersection, continue the approach and land prior to the intersection. If prior to the intersection, abandon the approach unless a landing is assured well before reaching the intersection and avoid flight below the larger aircraft's flight path.
- If departing behind a larger aircraft, note the larger aircraft's rotation point and rotate prior, and then continue to climb above the larger aircraft's climb path until turning clear of its wake. Avoid subsequent headings crossing below and behind a larger aircraft. Be alert for any critical takeoff situation possibly leading to a vortex encounter.
- For intersection takeoffs on the same runway, remain alert for adjacent large aircraft operations particularly upwind of the runway. Avoid headings crossing below a larger aircraft's path.
- When departing or landing after a larger aircraft executing a low approach, missed approach or touch-and-go landing, because vortices settle and move laterally near the ground, the vortex hazard may exist along the runway and in the flight path after a larger aircraft has executed a low approach,

missed approach or a touch-and-go landing, particularly in light quartering wind conditions. Ensure an interval of at least two minutes has elapsed before takeoff or landing.

- When en route VFR, avoid flight below and behind a larger aircraft's path. If a larger aircraft is observed above on the same track (meeting or overtaking), adjust position laterally, preferably upwind.

AVIATOR RESPONSIBILITY

6-123. Government and industry groups are making concerted efforts to minimize or eliminate hazards of trailing vortices; however, the flight discipline necessary to ensure vortex avoidance during VFR operations must be exercised by the aviator. Vortex visualization and avoidance procedures are exercised by the aviator using the same degree of concern as in collision avoidance.

6-124. Aviators are reminded in operations conducted behind all aircraft, acceptance of instructions from ATC in the following situations is an acknowledgement that the aviator ensures safe takeoff and landing intervals and accepts responsibility for providing wake turbulence separation:

- Traffic information.
- Instructions to follow an aircraft.
- Acceptance of a visual approach clearance.

6-125. For operations conducted behind heavy aircraft, ATC specifies the word "heavy" when this information is known.

6-126. For VFR departures behind heavy aircraft, air traffic controllers are required to use at least a 2-minute separation interval unless an aviator has initiated a request to deviate from the 2-minute interval and indicated acceptance of responsibility for maneuvering the aircraft, thereby avoiding wake turbulence hazard.

AIR TRAFFIC CONTROL WAKE TURBULENCE SEPARATION

6-127. Aircrews should exercise caution and adhere to ATC separation requirements. Extra time and fuel requirements must be considered during the planning process if operating around large aircraft due to wake turbulence.

Behind Heavy Jets

6-128. Due to possible effects of wake turbulence, controllers are required to apply no less than specified minimum separation for aircraft operating behind a heavy jet and, in certain instances, behind large non-heavy aircraft.

6-129. Separation is applied to aircraft operating directly behind a heavy jet at the same altitude or less than 1,000 feet below—

- Heavy jet behind heavy jet—4 miles.
- Small/large aircraft behind heavy jet—5 miles.

6-130. Also, separation, measured at the time the preceding aircraft is over the landing threshold, is provided to small aircraft—

- Small aircraft landing behind heavy jet—6 miles.
- Small aircraft landing behind large aircraft—4 miles.

6-131. Additionally, departing aircraft are separated by either two minutes or the appropriate 4 or 5 mile radar separation when takeoff behind a heavy jet is—

- From the same threshold.
- On a crossing runway and projected flight paths cross.
- From the threshold of a parallel runway when staggered ahead of the adjacent runway by less than 500 feet and when runways are separated by less than 2,500 feet.

6-132. Aviators, after considering possible wake turbulence effects, may specifically request a waiver of the 2-minute interval. Controllers may acknowledge this statement as aviator acceptance of responsibility for wake turbulence separation and, if traffic permits, issue takeoff clearance.

Behind Larger Aircraft

6-133. A 3-minute interval is provided when a small aircraft will takeoff—

- From an intersection on the same runway (same or opposite direction) behind a departing large aircraft.
- In the opposite direction on the same runway behind a large aircraft takeoff or low/missed approach.
- This 3-minute interval may be waived upon specific aviator request.

6-134. Controllers may not reduce or waive the 3-minute interval if the preceding aircraft is a heavy jet and operations are on either the same runway or parallel runways separated by less than 2,500 feet.

6-135. Aviators may request additional separation, that is, two minutes instead of 4 or 5 miles for wake turbulence avoidance. This request is made as soon as practical on ground control and at least before taxiing onto the runway.

6-136. Controllers may anticipate separation and need not withhold a takeoff clearance for an aircraft departing behind a large/heavy aircraft if there is reasonable assurance required separation exists when the departing aircraft starts takeoff roll.