XIV.C. Flight Principles – Engine Inoperative

References: Airplane Flying Handbook (FAA-H-8083-3), POH/AFM

Objectives	The student should develop knowledge of the elements related to single engine operation.
Key Elements	1. Left Engine is Critical 2. Never go below V_{MC} 3. Maintain directional control (Fly the Airplane!)
Elements	1. Critical Engine 2. V_{MC} Demonstration 3. V_{MC} and Loss of Control 4. V_{MC} and Stall Speed 5. V_{YSE} 6. Engine Failure During / After Lift-Off
Schedule	1. Discuss Objectives 2. Review material 3. Development 4. Conclusion
Equipment	1. White board and markers 2. References
IP's Actions	1. Discuss lesson objectives 2. Present Lecture 3. Ask and Answer Questions 4. Assign homework
SP's Actions	1. Participate in discussion 2. Take notes 3. Ask and respond to questions
Completion Standards	The student understands the differences between a single and multiengine airplane as well as the elements of an engine failure, the critical engine, and V_{MC}.

Instructor Notes:

Introduction:

Attention

Interesting fact or attention-grabbing story

Overview

Review Objectives and Elements/Key ideas

What

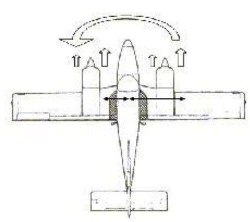
Having an additional engine is helpful for better climb performance and greater speeds, but a failure of one of the engines introduces a situation very different from losing an engine in a single engine airplane. In this lesson you will learn which engine has a more adverse effect on control and performance when lost and why, as well as what the minimum controllable airspeed is, and finally how to manage an engine failure.

Why

In the case of an engine failure it is essential a pilot understands the elements involved and can maintain control of the airplane.

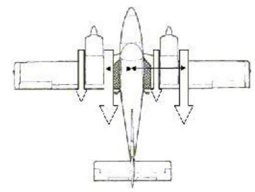
How:

1. **Critical Engine**
   - A. Definition: The engine whose failure would most adversely affect the performance or handling qualities of an aircraft
   - B. In a conventional twin, with both props rotating clockwise, this is the LEFT engine
     - i. Other twins overcome the problem of a critical engine with counter-rotating propellers
   - C. There are 4 factors responsible for the left engine being critical on a conventional twin
     - i. P-Factor, Accelerated Slipstream, Spiraling Slipstream, and Torque (Remember: PAST)
   - D. P-Factor

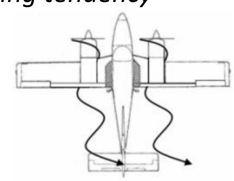


     - i. The descending blade of each propeller produces more thrust than the ascending blade
       - a. Therefore, in a conventional twin, the center of thrust is offset to the right of each engine
     - ii. There is a greater distance (arm) between the center of thrust and the longitudinal axis on the right engine than on the left
       - a. The greater the distance, or arm, the greater the leverage
     - iii. If the right engine fails the leverage associated with P-Factor is not as great as if the left engine fails
     - iv. If the left engine fails the yaw from P-Factor is most adverse, therefore the left engine is critical
   - E. *Accelerated Slipstream*
     - i. *Due to P-Factor, there is greater airflow (more lift) over the wings on the right side of each engine*

- ii. *There is a greater distance (arm) between the excess lift and the longitudinal axis on the right engine than on the left engine*
    - a. *The greater the distance, or arm, the greater the leverage*
- iii. *If the left engine fails, there is a stronger rolling action than if the right engine fails, therefore the left engine is critical*



F. Spiraling Slipstream
- i. *Each propeller produces a spiraling slipstream of air behind it (picture)*
- ii. *The left engine's slipstream strikes the rudder on the left side creating a left turning tendency*
- iii. *The right engine's slipstream has no affect on the aircraft*
- iv. *If the right engine fails the left engine's slipstream will counteract some of the yaw toward the dead engine*
- v. *If the left engine fails the airplane will yaw uninhibited toward the dead engine, therefore the left engine is critical*



G. Torque
- i. Torque is based on Newton's 3rd law: For every action there is an equal and opposite reaction
- ii. When the propellers spin clockwise torque will cause the plane to roll counter-clockwise (CCW) (picture)
- iii. If the right engine fails the plane will roll to the right, but the CCW torque will offset some of the force
- iv. If the left engine fails the CCW torque will encourage the roll toward the left engine
- v. The left engine is critical since torque most adversely affects control when the left engine fails

2. *V_{MC} & V_{MC} Demonstration*

A. *In aircraft certification, V_{MC} is the sea level calibrated airspeed at which, when the critical engine is suddenly made inoperative, it is possible to maintain control of the airplane with that engine still inoperative and then maintain straight flight at the same speed with a bank angle of not more than 5^o*
- i. *Red line on airspeed indicator*

B. *V_{MC} is not a fixed airspeed under all conditions*
- i. *Only a fixed speed for the specific set of circumstances under which it was tested during certification*
- ii. *Specific circumstances required by the FAA*
    - *Maximum takeoff power*
    - *Critical engine inoperative*
    - *Inoperative engine windmilling*
    - *Sea level conditions*
    - *Most adverse legal weight*
    - *Most adverse legal CG*
    - *Maximum 5^o bank into the operative engine*
    - *Gear up*
    - *Flaps takeoff position*
    - *Cowl flaps open*
    - *Out of ground effect*
- i. *Specific circumstances seem to depict a specific scenario*
    - a. *Engine failure after takeoff with the gear up so the pilot is committed to flying*
- ii. *V_{MC} varies with a variety of factors*

B. *V_{MC}* Factors Explained
- i. Maximum Available Takeoff Power – Bad for V_{MC}
    - a. V_{MC} increases as power is increased on the operating engine
    - b. The greater the power, the greater the force pulling toward the dead engine
- ii. Critical Engine Wind Milling – Bad for V_{MC}
    - a. V_{MC} increases with increased drag on the inoperative engine

   b. V_{MC} is highest when the critical engine prop is wind milling at the low pitch, high rpm blade angle
iii. Sea Level Conditions – Bad for V_{MC}
   a. V_{MC} decreases with increases in altitude or a decrease in density
   b. Due to reduced thrust at higher density altitudes, less yaw is experienced in relation to P-Factor
iv. Most Unfavorable Weight (lightest) – Bad for V_{MC}
   a. V_{MC} is increased as weight is reduced
   b. A heavier plane is a more stable and controllable plane
   c. Also, the weight of the airplane assists in establishing and maintaining a zero-side slip
v. Most Unfavorable CG (aft) – Bad for V_{MC}
   a. V_{MC} increases as the CG is moved aft
   b. The moment of the rudder arm is reduced, and therefore its effectivity is reduced
   c. AND, the moment arm of the propeller blade is increased, aggravating asymmetrical thrust
vi. Landing Gear Retracted – Bad for V_{MC}
   a. V_{MC} increases when the landing gear is retracted
   b. Extended gear aids in directional stability, which tends to decrease V_{MC}
vii. Flaps in the takeoff Position - ?? for V_{MC}
   a. Takeoff position, amount of extension, and type of flap varies by aircraft
   b. If the flaps are down, they tend to decrease V_{MC}
      - Creates extra drag on the operating engine
      - Reduces tendency to yaw toward the inoperative engine
      - For this reason, we'll say flaps down decreases V_{MC} and up increases V_{MC}, but…
   c. Extended flaps could also increase V_{MC}
      - May create extra lift on the operating engine side increasing roll toward the dead engine
viii. Cowl Flaps in the takeoff position – Good for V_{MC}
   a. Open cowl flaps will produce more drag on the operative engine, therefore decreasing V_{MC}
ix. Airplane Trimmed for Takeoff - ?? for V_{MC}
   a. This varies between aircraft due to different T-tail, low tail, type of elevator and trim setting
x. Airplane Airborne and Out of Ground Effect – Bad for V_{MC}
   a. In ground effect, as the plane yaws and rolls toward the dead engine, the wingtip dips further into ground effect
      - Drag is reduced, reducing yaw toward the dead engine
   b. Out of ground effect, this support does not exist
xi. Maximum 5^{o} of Bank – Good for V_{MC}
   a. V_{MC} is highly sensitive to bank angle
      - To prevent claims of unrealistically low speeds, the bank into the operating engine is limited
   b. Bank's horizontal component of lift assists the rudder in countering the asymmetrical thrust
   c. V_{MC} is reduced significantly with increases in bank and increases significantly with decreases

- Tests have shown that V_{MC} may increase > 3 knots for each degree of bank less than 5°

C. Aircraft Control, V_{MC}, and Performance
   i. As control decreases, V_{MC} increases
   ii. For the most part, increased performance also leads to a higher V_{MC}
      a. Exceptions: Windmilling propeller, ground effect, and bank angle

Factor	Control	V_{MC}	Performance
Wind Milling Prop	Decreases	Increases (Bad)	Decreases
Max T/O Power	Decreases	Increases (Bad)	Increases
Sea Level (Low DA)	Decreases	Increases (Bad)	Increases
Light Weight	Decreases	Increases (Bad)	Increases
Aft CG	Decreases	Increases (Bad)	Increases
Gear Up	Decreases	Increases (Bad)	Increases
Takeoff Flaps (Up)	Decreases	Increases (Bad)	Increases
Takeoff Cowl Flaps (Open)	Increases	Decreases (Good)	Decreases
Trimmed for T/O	?	?	?
Airborne / Out of GE	Decreases	Increases (Bad)	Decreases
Bank Angle (Up to 5°)	Increases	Decreases (Good)	Increases

3. V_{MC} and Loss of Control

A. Control is lost when the moment of the thrust arm of the operating engine exceeds that of the rudder
   i. The rudder cannot maintain control and the plane yaws in the direction of the inoperative engine

B. Loss of control is indicated when full rudder is applied into the operating engine and the airplane continues to yaw toward the inoperative engine
   i. It can be seen visually with a visual reference point or on the heading indicator

C. The proper pitch and bank attitude should be maintained in order to obtain an accurate V_{MC} speed
   i. Without the zero-side slip condition, V_{MC} will increase and directional control may be lost early

D. Recovery
   i. The moment uncontrollable yaw or any symptom associated with a stall is recognized, recover
   ii. The operating engine throttle should be retarded as pitch attitude is decreased
      a. Retarding the throttle will tend to fix the yawing problem (the thrust moment is reduced)
      b. Decreasing pitch increases airspeed, making the rudder more effective
      c. By reducing power, you are decreasing the amount of yaw the rudder has to overcome and by pitching forward you are increasing the amount of force the rudder can produce
   iii. Recovery is made to straight flight at V_{YSE} with the operating engine throttle reintroduced

4. **V_{MC} and Stall Speed**
    - A. V_{MC} decreases with altitude, while stall speed remains the same
        - i. The margin between stall speed and V_{MC} decreases with altitude
    - B. Should a stall occur with asymmetric power, a spin is likely
        - i. Airplane will spin in the direction of the idle engine
        - ii. Twins are not required to demonstrate spin recovery
    - C. Coffin Corner: Altitude where V_{MC} and V_S are the same
        - i. Above this altitude, V_{MC} will occur after a stall
        - ii. Extremely dangerous area
    - D. When a stall occurs prior to V_{MC}, departure from controlled flight can be sudden
        - i. Yawing and rolling, possibly inverted, and a spin
    - E. Terminate immediately, if during a V_{MC} demo, there are any symptoms of an impending stall
5. **V_{YSE}**
    - A. Best rate of climb speed with one engine inoperative
        - i. Pitch is lower relative to V_Y
    - B. If above the single engine absolute ceiling when the engine fails, the airplane slowly loses altitude
        - i. V_{YSE} minimizes the rate of descent
    - C. Very important to maintain ≥ V_{YSE} at all times when single engine
        - i. V_{XSE} is an exception (short field takeoff / obstacles) but is perilously close to V_{MC}
            - a. Be extremely cautious
        - ii. Very important to maintain proper pitch attitude for safe flight, especially close to the ground
6. **Engine Failure During / After Lift-Off**
    - A. A takeoff or go around is the most critical time to suffer an engine loss
        - i. The airplane will be slow, close to the ground and flaps and gear may even be extended
        - ii. Altitude and time will be minimal
    - B. Engine Failure
        - i. Maintain control
        - ii. Pitch to maintain V_{YSE} (do not ever slow below V_{MC})
            - a. Extremely important
        - iii. Engine failure procedures
    - C. Complete failure of an engine can be summarized into three scenarios:
        - i. Landing Gear Down (if gear is still down, runway is still remaining to land on)
            - a. If failure occurs before selecting the Gear Up, close both throttles and land on the remaining runway
        - ii. Landing Gear Up, single engine climb inadequate
            - a. A landing must be accomplished on whatever lies ahead
            - b. A descent at V_{YSE} is possible to extend the time before reaching the ground
        - iii. Landing Gear Up, single engine climb adequate
            - a. The procedures for continued flight should be followed
                - Control
                - Configuration - Full Power, Gear up, Flaps up, Identify, Verify, Fix, Feather
                - Climb
                - Checklist (If time)
    - D. Plan Ahead – Brief emergency procedures, V_{YSE}, V_{MC}
        - i. If an engine is lost on the roll, reduce power to idle, maintain directional control
        - ii. If an engine is lost after rotation and the gear is still down, maintain control and land ahead

iii. If an engine is lost after rotation and the gear is up, maintain control, configure to return for landing

Conclusion:
Brief review of the main points

PTS Requirements:
To determine that the applicant exhibits instructional knowledge of the elements related to flight principles engine-inoperative by describing:

1. Meaning of the term “critical engine.”
2. Effects of density altitude on the V_{MC} demonstration.
3. Effects of airplane weight and center of gravity on control.
4. Effects of bank angle on V_{MC}.
5. Relationship of V_{MC} to stall speed.
6. Reasons for loss of directional control.
7. Indications of loss of directional control.
8. Importance of maintaining the proper pitch and bank attitude, and the proper coordination of controls.
9. Loss of directional control recovery procedures.
10. Engine failure during takeoff including planning, decisions, and single-engine operations.