



## ***St. Charles Flying Service, Inc.***

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# **Multi-Engine Training Packet**

This multi-engine training course is designed for the Commercial Multi-Engine Rating, MEI and ATP.

This packet, in conjunction with a BE-76 Pilot's Operating Handbook contains all the information you need for the multi-engine course.

Success in this training course depends on your study preparation and your instrument flying proficiency.



# *St. Charles Flying Service, Inc.*

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# Program Itinerary

This study packet is designed for commercial-multi, ATP and MEI candidates.

The training schedule is flexible but fairly standard.

\*Note\* The applicant should be instrument current and proficient.

## Day 1

Approximately 4 hours of flight training  
Ground instruction as required for the rating

## Day 2

Prep for oral exam  
Brush-up/practice checkride flight  
Checkride

Below are training outlines for each specific rating. The key to success and minimal stress is preparation. With the exception of the actual BE-76 flight manual, this packet contains everything you need for the multi-engine course.

### Airline Transport Pilot

Airwork (IR):

- Steep turns
- Slow flight at minimum controllable airspeed
- Approaches to stalls
- Engine failure (takeoff roll, climb, cruise)
- Traffic patterns (normal and single engine)
- Go arounds (normal and single engine)
- Manual gear extension procedures
- No flap landing

Instrument Approaches:

All will be at St. Louis Regional Airport in Alton, IL (ALN).

1. VOR-A: no gyro
2. ILS 29: straight-in landing
3. ILS 29: single engine, circle-to-land
4. NDB 29: published missed approach

### Commercial-Multi and MEI

Airwork (VR):

- Steep turns
- Slow flight
- Power on/off stalls
- Engine failure (takeoff roll, climb, cruise)
- V<sub>mc</sub> - Loss of directional control demonstration
- Traffic patterns (normal and single engine)
- Go arounds (normal and single engine)
- Manual gear extension procedures
- No flap landing

Instrument Approaches:

Applies only to applicant who desire instrument privileges.  
Does not apply to MEI candidates.  
VOR-18 at SET and/or VOR-9 at 3SQ 2 engine and single engine

Note: Any approach at any airport in the area is an option for the examiner.  
The above approaches however are most likely the ones that will be used

# Flying Light Twins (General)

The most important phase of multi-engine flying is: Preflight Planning  
Most critical phase of light twin flying is: Takeoff

FAR Part 23 involves certifying light twins with a max gross weight of less than 12,500 lbs.

## Certification Requirements:

At 5,000 ft. international standard atmosphere the airplane performance must be determined by the manufacturer for certification.

6001 - 12,500 lbs. -

Must climb clean at 5,000 ISA

$$\text{ROC} = (.027 \times V_{so}^2)$$

6,000 lbs. or less -

If  $V_{so} = 61$  kts. CAS (important) or  $>$  Must perform a positive ROC ( $.027 \times V_{so}^2$ )

If  $V_{so} =$  less than 61 kts. CAS. Does not have to do anything. Can be negative ROC.

Examples:

C-310

5,300 lbs.

$V_{so} = 63.9$  kts.

$63.92 \times .027 = 110.2$  fpm ROC

reality ROC = 119 fpm

Aztec

less than 6,000 lbs

$V_{so} = 60.8$  kts.

reality ROC = 50 fpm

Lose one engine and loss of climb performance is approximately 80% which leaves 20% climb capability. Due to asymmetrical thrust and drag and the control responses necessary to compensate for these factors. Refer to chart in "Leave Yourself an Out."

## Cessna 310 Figures

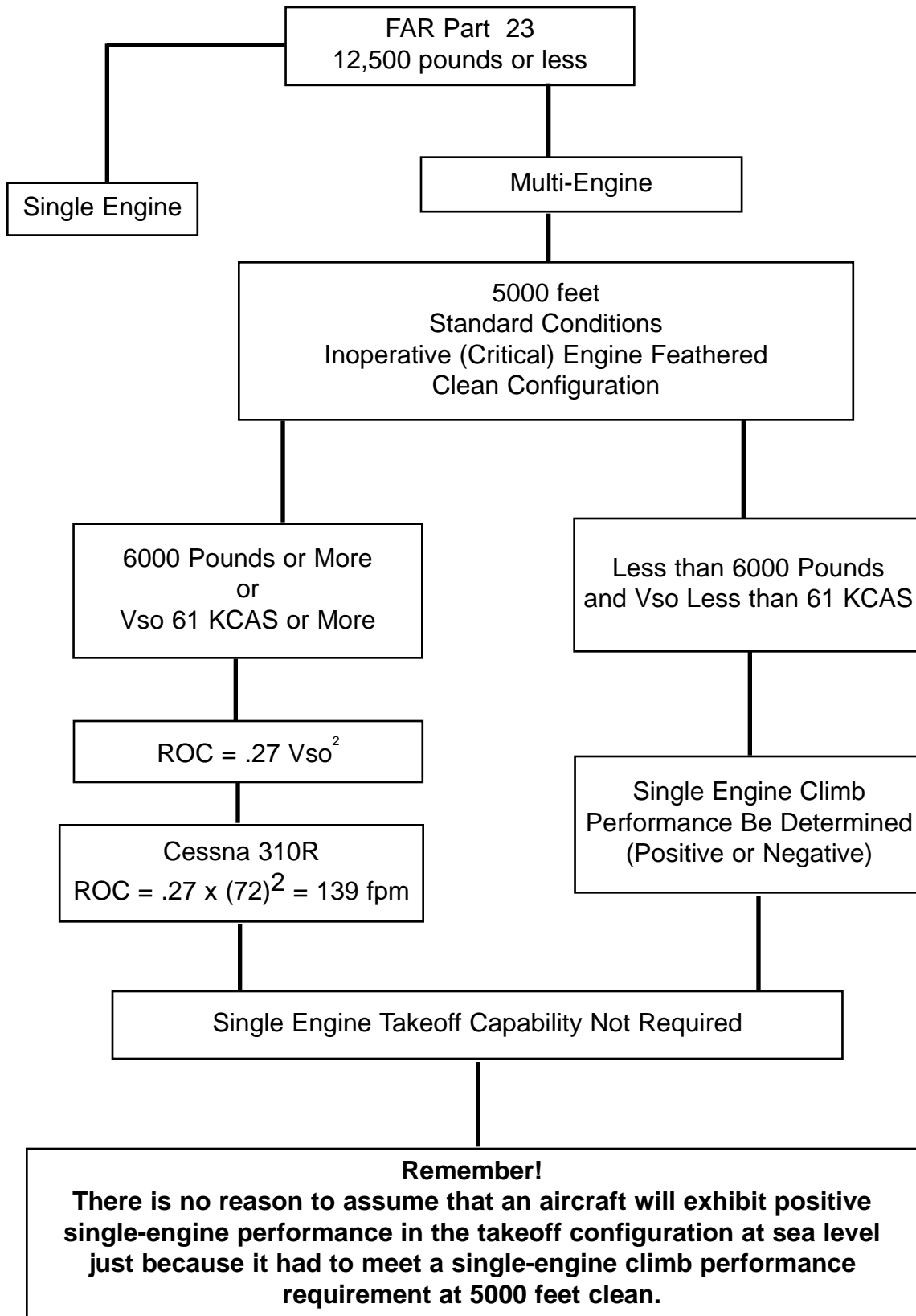
2 engine ROC = 1,495

1 engine ROC = 327 (78.13% loss)

## 3 Factors of Safety

1. Loss of directional control (30%) roll over
2. Inadequate climb performance (CP) (42%) maneuvering to get back to land
3. Stall/Spin (26%)

Correct airspeed is critical! Altitude is life but airspeed is critical in order to maintain directional control and maximum climb performance in a single engine situation.



# V<sub>mc</sub>

## Velocity of Minimum Controlable Airspeed

### Determining V<sub>mc</sub>

Emphasis on directional control  
Red radial (never higher but can be lower)

V<sub>mc</sub> is the minimum airspeed with the critical engine failed at which it is possible to maintain directional control of the airplane within 20 degrees heading change and maintain straight flight with not more than 5 degrees bank into good engine. It is determined in a 0 sideslip condition. V<sub>mc</sub> guarantees directional control only.

### How is it determined?

#### COMBATS

Critical engine failed/windmilling  
Operating engine T/O power  
Max gross weight  
Bank 3° to 5° into good engine  
Aft CG  
Takeoff configuration  
Standard day 29.92 15°C

- **Standard day 59 degrees Fahrenheit at sea level.**

Note: V<sub>mc</sub> will be lower with higher density altitude and/or hotter temperature.

The engine will develop more power in standard conditions.

In normally aspirated aircraft V<sub>mc</sub> decreases with an increase in density altitude due to the output of the operative engine which decreases thus the asymmetrical power situation decreases. This seems good but as V<sub>mc</sub> approaches stall and if they are reached simultaneously, a spin is almost inevitable.

- **Takeoff configuration with critical engine failed.**

With landing gear extended it tends to decrease V<sub>mc</sub> in most twins but can be good and bad. Acts as a stability device acting as a weather vane to decrease yaw

ing tendency but also creates a lot of drag. Determined with gear retracted.

- **Rearmost allowable CG. Forward V<sub>mc</sub> is lower, aft V<sub>mc</sub> is higher.**

With an aft CG, the force of the rudder is reduced to a shorter arm and consequently reduced turning moment.

- **Flaps in takeoff position.**

- **Operating engine producing maximum continuous power.**

Will create more lift and produce more of a yawing tendency about the longitudinal axis.

- **Propeller windmilling in TO pitch configuration (or feathered if automatically featherable)**

Windmilling prop creates more drag than a feathered prop.

- **Maximum 5 degrees bank into good engine.**

V<sub>mc</sub> is likely slower since these conditions are the worst case scenario and most engine failures rarely occur with all of the factors listed above.

V<sub>mc</sub> cannot be greater than 1.2 times stall speed with flaps in takeoff position and gear retracted.

V<sub>mc</sub> is not a static number like flap operating speed or never exceed speed. It changes with conditions.

# Critical Engine

## Multi Engine Aerodynamics

Engine whose failure would most adversely affect performance or handling qualities of the airplane.

Produces the most adverse yaw. (See figure 1)

### Slow Flight

Less air is flowing over the control surfaces making them less effective.

Eventually the thrust of the engine overcomes the input from the control pressures and begins to pull and lift the airplane to the left. (See Figure 1 & 2)

### Drag

During single engine operations there are many factors contributing total drag and the loss of lift.

The failed engine creates a loss of induced lift on the wing. (See Figure 2)

The windmilling prop provides for a substantial amount of drag. (flat disc) (See Figure 1 & 2)

The use of flight controls to counteract the rolling and yawing produces drag. (See Figure 1)

### P-factor

Descending blade of each prop is producing more thrust than the ascending blade. (P-factor)

Because of this, the thrust acting parallel to the longitudinal axis through the wing mounted engines is moved to the right of each engine.

This causes the moment arm of the right engine to be greater than the left engine when compared to the longitudinal axis of the airplane.

### Torque

Torque also tends to roll the airplane in the opposite direction of rotation.

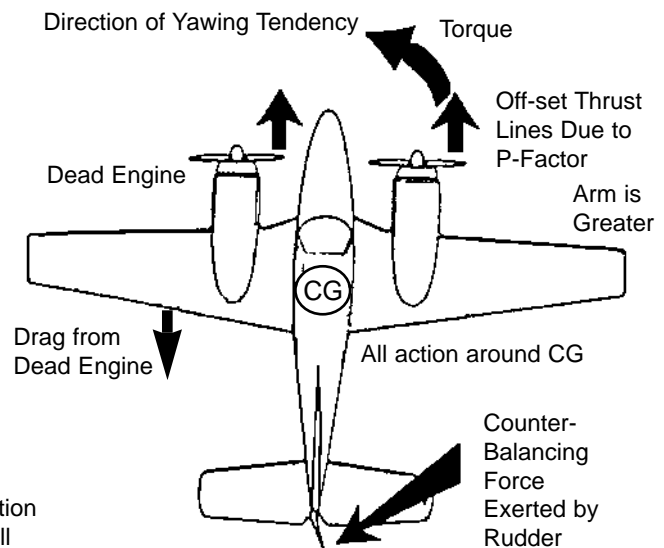


Figure 1

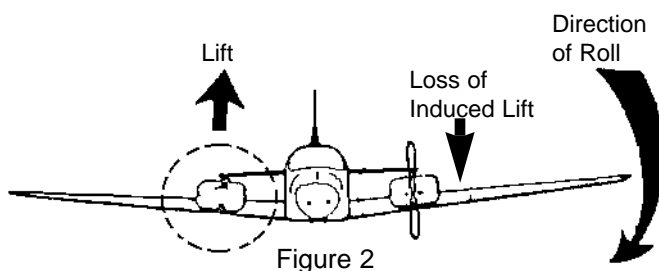


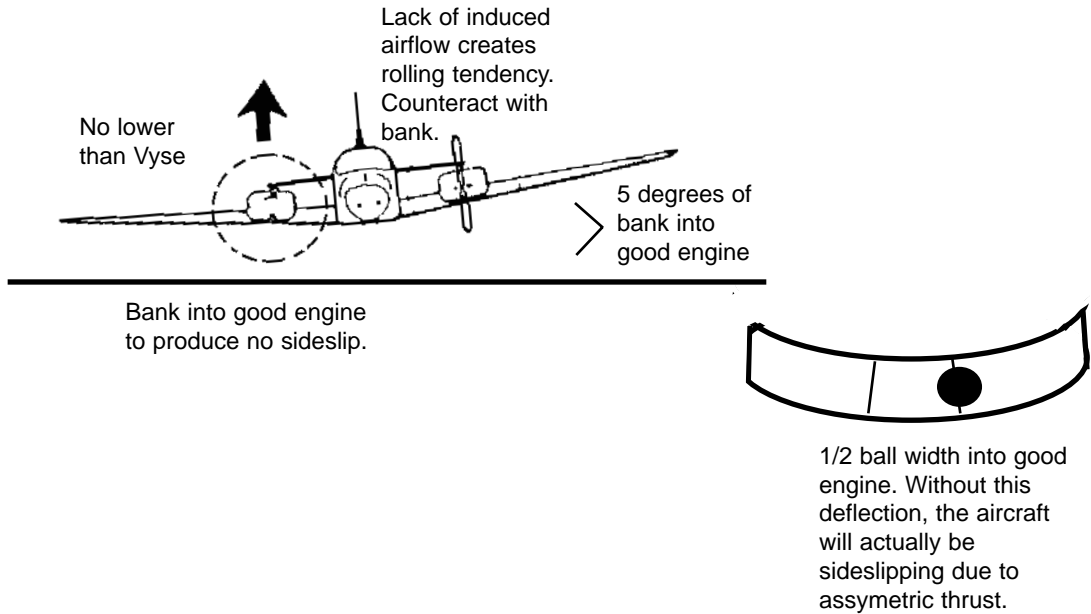
Figure 2

# Inadequate Climb Performance (C.P.)

Rule of Thumb - Ball will be 1/2 ball width into good engine.

Zero Sideslip = Max Single Engine Climb Performance.

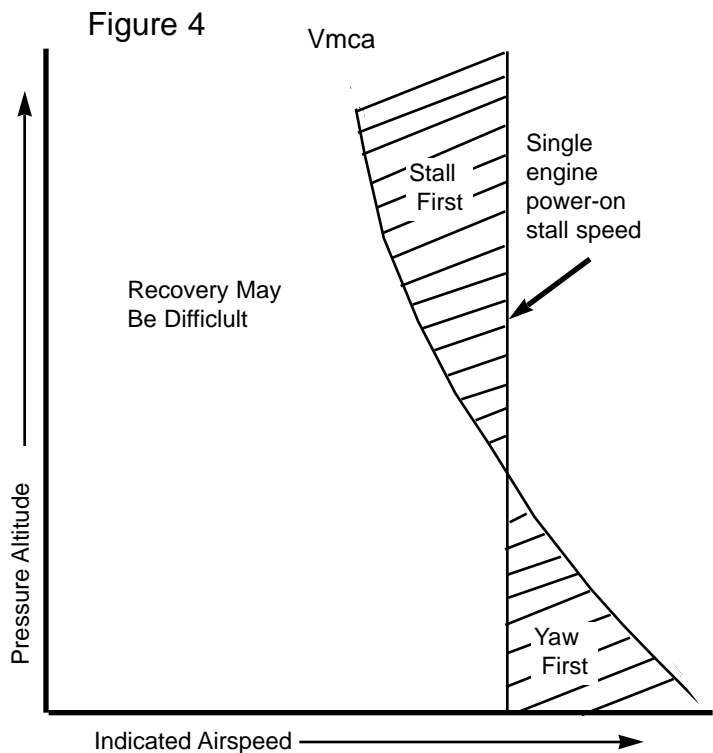
Use whatever bank gets the best vertical speed.



## Stall/Spin

### Vmc vs. Stall Speed

- The manufacturer's published minimum control speed and actual Vmc may vary as the power on the noncritical engine changes.
- Normally aspirated engines lose efficiency as altitude increases and are unable to develop 100% rated sea level power.
- This power loss causes Vmc to decrease- however, the stalling speed remains the same.
- Eventually the two speeds will be at the same point.



## Service Ceiling

Maximum density altitude where the best rate of climb airspeed will produce a 100 fpm climb at gross weight with both engines at max continuous power.

## Absolute Ceiling

Max density altitude the airplane is capable of attaining or maintaining at gross weight in the clean configuration and max continuous power. As altitude increases,  $V_x$  increases, while  $V_y$  decreases, where the 2 speeds converge is the absolute ceiling

## Single Engine Service Ceiling

Max density altitude which the rate of climb is 50 fpm with one engine inoperative in smooth air with one engine feathered at  $V_{yse}$ . Single engine service ceiling chart should be used during flight planning to determine whether the airplane as loaded can maintain the MEA if IFR or terrain clearance if VFR single engine. Know your single engine service ceiling especially when crossing mountainous terrain.

## Turning

To turn the airplane in smooth air and maintain altitude you must have at least 50 fpm ROC capability.

## Takeoff

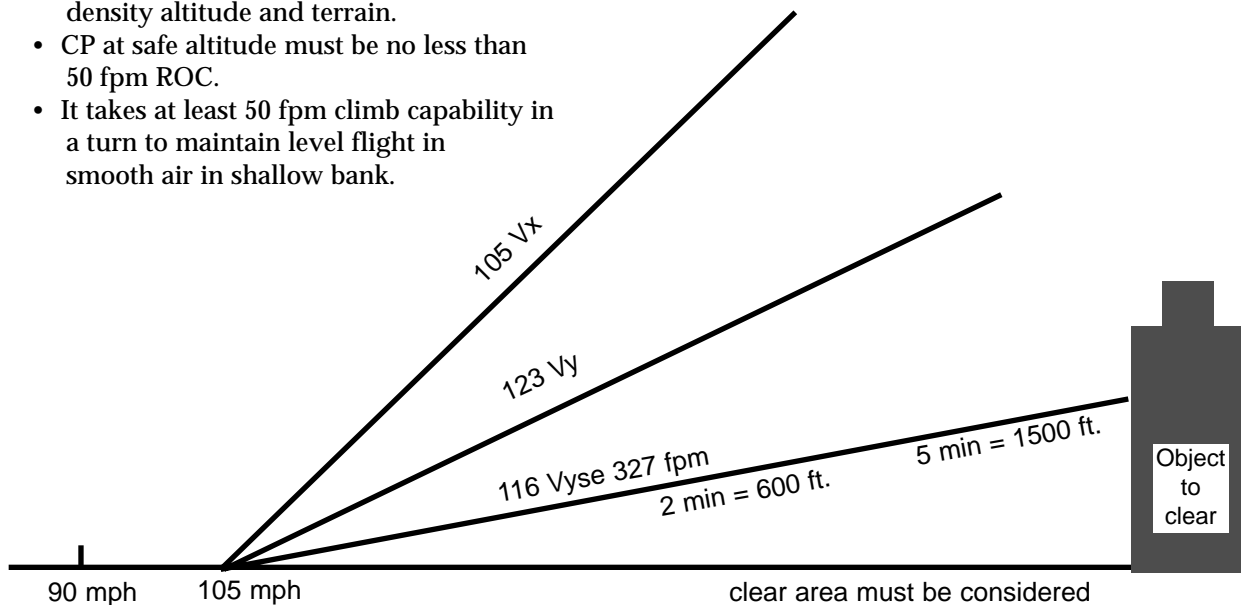
You need to know climb performance at safe altitude (1000 ft. AGL; 2000 ft. in mountainous terrain)

- It's up to you to choose a "safe" altitude.
- Determining safe altitude - varies due to density altitude and terrain.
- CP at safe altitude must be no less than 50 fpm ROC.
- It takes at least 50 fpm climb capability in a turn to maintain level flight in smooth air in shallow bank.

If airspeed 105 mph - ABORT

If airspeed 105 mph or greater and runway remains - ABORT

If airspeed 105 mph or greater and no runway remains - ?



### Light-Twin Initial Climb Accident Factors

Cause	Accidents	Fat/Inj.	Avg. bal.
Loss of direct. control	30%	35%	32%
Stall / Spin	26%	38%	32%
Inad. climb perf.	43%	25%	34%

*Conclusion of Five Degree Forever Syndrome (FDF)*

### **Rules of Thumb**

#### **Rule #1**

Never allow airspeed to drop below  $V_{mc}$  except during last few yards of the landing flare, and then only if the field is extremely short.

#### **Rule #2**

An airplane that has all engine  $V_x$  speed less than  $V_{mc}$  should only be used in an emergency situation to clear obstacles and then be very cautious.

#### **Rule #3**

Rotate at least  $V_{mc} + 5$  never at  $V_{mc}$  or below in case of engine failure. Use the manufacturer's recommended liftoff speed or  $V_{mc} + 5$  whichever is greater.

#### **Rule #4**

After leaving the ground above  $V_{mc}$ , climb no slower than  $V_{yse}$  and not faster than  $V_y$ .  $V_y$  is preferable if obstacles are not a consideration.

Reason: If an engine fails while you're holding  $V_y$ , the deceleration while you are getting things straightened out will probably put you pretty close to  $V_{yse}$  (blue line) which is where you want to be.

#### **Rule #5**

Be a skeptic when reading the performance tables in your Part 23 aircraft owners manual and be sure to read the fine print. Add plenty of fudge factors. (About 10%)

Read: Summing Up in "Leave Yourself An Out."

# General Procedures & Airspeeds

## Intentional One-Engine Inoperative Speed (Vsse)

-Minimum speed which to perform intentional engine cuts.

## Best Single Engine Rate-of-Climb Speed (Vyse)

- Blue line
  - Best single engine performance (may not be a climb)
1. Critical engine inoperative, and its prop in minimum drag position.
  2. Operating engine set at not more than max. continuous power.
  3. Gear retracted.
  4. Flaps in most favorable (best lift/drag ratio) position.
  5. Cowl flaps as required for engine cooling.
  6. Airplane flown at recommended bank angle.

## Action After Dead Engine

- POWER UP
  - mixture up
  - props up
  - throttles up
- CLEAN UP
  - flaps up
  - gear up
  - aux fuel pumps on
- IDENTIFY
  - "Dead foot, dead engine"
- VERIFY
  - cautiously retard throttle
- RECTIFY
  - Checklist for possible restart if conditions permit
- SECURE
  - feather prop
  - mixture idle cut-off
  - see checklist

## Basic Single-Engine Procedures

- Cardinal Rule #1 - Maintain control and airspeed at all times.
- Usually apply max. power to operating engine.
- Reduce drag to a absolute minimum.
- Secure failed engine and related sub-systems.

As soon as directional control is established and the airplane is configured for climb, reduce the bank angle to produce zero slip (ZS) and best performance. (Note: Without specific guidance for ZS, a bank of 2 degrees or one-half ball deflection is suggested.)

## Engine Failure On Takeoff

1. Before Takeoff - Abort (throttles idle)
2. After liftoff - gear down with runway remaining - Abort.
3. If not able to climb, pull power on the good engine and land straight ahead. Don't try to force a climb and lose control.

## Accelerate - Go Distance

Distance required to accelerate to liftoff speed and, assuming failure of an engine at the instant liftoff speed is attained, to continue takeoff on the remaining engine to a height of 50 ft.

Know before you try to take off whether you can maintain control and climbout if you lose an engine while gear is still down. It may be necessary to off-load some weight, or wait for more favorable temp. or wind conditions.

## Accelerate - Stop Distance

Distance required to accelerate to liftoff speed and, assuming failure of an engine at the instant liftoff speed is attained. Throttle to idle, maximum braking and stop.

# General Procedures & Airspeeds

## When to fly $V_x$ , $V_y$ , $V_{xse}$ , and $V_{yse}$

- Two engines operating: fly  $V_y$  (or  $V_x$  if obstacle) on initial climb out. Then accelerate to cruise climb which may be 10-15 kts. greater than  $V_y$  after obtaining safe altitude. -
- At first indication of an engine failure during climb-out, or on the approach, establish  $V_{yse}$  or  $V_{xse}$  as appropriate.
- Climb rate is a function of the excess horsepower available, beyond the amount required for level flight.  
 $ROC = (\text{Excess hp}) (33,000 / \text{weight})$
- Optimum climb performance angle of bank can be neither 5 degrees nor any single value. Rather it depends on the airplanes geometry and weight, the density altitude and other minor factors.
- In marginal performance situations, when tolerance for error is least, it is at the minimum and far less than 5 degrees.
- Zero slip (ZS) is the best conditions. Banking beyond ZS incurs a stiff performance penalty in return for slightly reduced rudder pressure.

## Single Engine Go-Arounds

Must be begun several hundred feet AGL and at or above  $V_{yse}$ . If below blue line and descending at approx. 500 fpm it will take a 200-500 ft. to accelerate to clean the airplane up and climb.

Establish an AGL altitude and minimum air-speed combination for yourself and your aircraft. If you are below this speed and altitude and a truck shows up on the runway, you are committed to land; do not attempt go-around, but land off to the side.

## Takeoff Planning

1. Compare density altitude with the single-engine service ceiling. High temp. and high elevations often result in a takeoff density altitude above the airplane's single-engine service ceiling.
2. Consider the runway requirements including takeoff ground roll and accelerate-stop distance.
3. Consider distance to clear obstacles especially single engine climb performance.
4. Review engine-out airspeeds and procedures just prior to each takeoff.

## Climb Planning

Cruise climb - slower ROC, but decreases total trip time, allows better forward visibility, better engine cooling, and increases passenger comfort.  $V_y$  - Used to reach favorable winds, weather.  $V_x$  - to clear obstacles.

## Enroute Planning

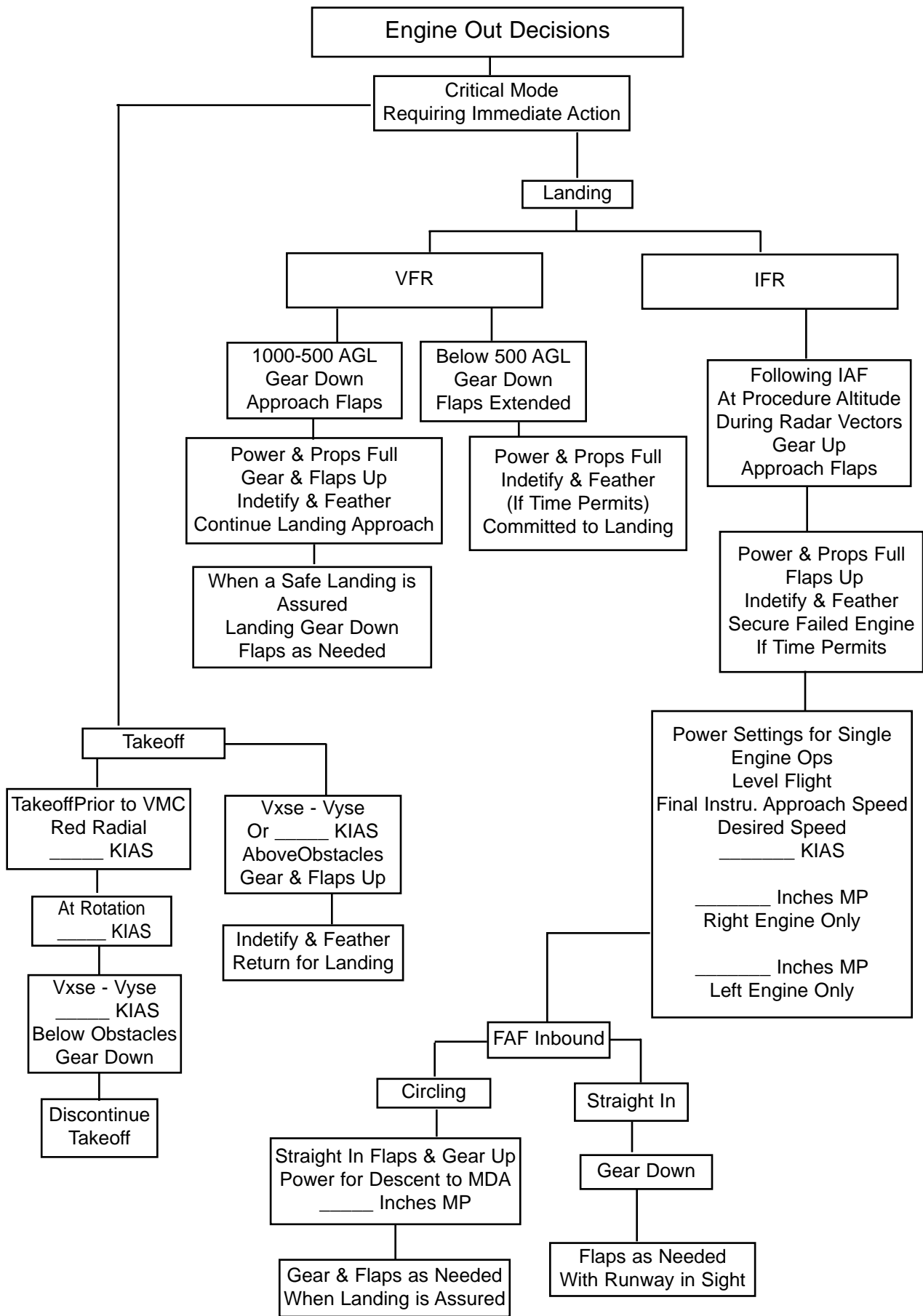
Consider single-engine service ceiling especially in mountainous areas where flight is conducted at altitudes in excess of the SE service ceiling. The pilot must have a plan of action during a gradual decent to the SE service ceiling.

## Starting Procedures

Everything is as normal and according to the checklist, Usually the checklist will specify which engine is to be started first, depending on the battery position. For example, if the battery is in the left wing, the left engine will be started first. This employs shorter battery cables and causes less energy loss to the left engine than the right.

## Taxiing

Use of differential power can be used in order to make tighter turns.



# General Procedures & Airspeeds

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# Weight & Balance

Max. Zero Fuel Weight

Max. weight exclusive of usable fuel limits the ratio of loads between the fuselage and wings.

## Center of Gravity Shift

If aft C.G. limits are exceeded, total moment must be reduced.

If forward limits are exceeded, total moments must be increased.

### Example:

Airplane loaded = 4,000 lbs.

Aft limit = 94.6 in.

Computed CG = 95.2 in.

Result = .6 in. aft the limits

### Solution:

Gross weight 4,000 lbs. x .6 in. = 2,400 lb. - in.

Next it must be determined where weight can be shifted to reduce this moment.

If the airplane has both forward and aft compartments some baggage can be moved forward.

### Solution:

Divide moment by distance it is being moved.

2,400 lb - in. - 156.2 in. = 15.4 lbs.

\*To load the airplane within limits approx. 15.5 lbs. must be moved to the forward compartment.

# General Systems

## Autofeather System

Installed on some high performance turbo-props to feather the props in the event of a power failure during takeoff.

## Reversible Prop System

Merely changes blade angle into the negative blade angle range to decrease landing roll.

## Fuel System

Know Your fuel system! Capacity of each tank. Fuel pumps involved with the system. Use of the fuel selector valves. Cross-feed system. Fuel vent locations to check during pre-flight. Fuel strainer locations.

## Fuel Injection System

- Fuel injection provides a more accurate method of measuring and distributing fuel to each cylinder.
- Overall fuel injection uses less fuel per unit of horsepower, increased horsepower per unit of engine weight, and lower operating temps.
- Refer to the POH on use of EGT and leaning of mixture.
- Be familiar with use of alternate air source and when it should be used.

## Electrical Systems

- Either 14 volt, or 28 volt DC systems.
- Usually two alternators, two voltage regulators and individual overvoltage relays to protect the electrical equipment in event of voltage regulator malfunction.
- Either 12 or 24 volt battery.

## Voltage Regulators: Two functions

1. Maintain proper electrical load-sharing between the two alternators.
2. Maintain a constant electrical system voltage.

### Overvoltage Relays:

After the electrical power passes through the regulator. If an overvoltage malfunction occurs and the alternator output exceeds the normal 14 or 28 system voltage, the relay trips and the alternator is taken off line. Consult the POH for corrective action.

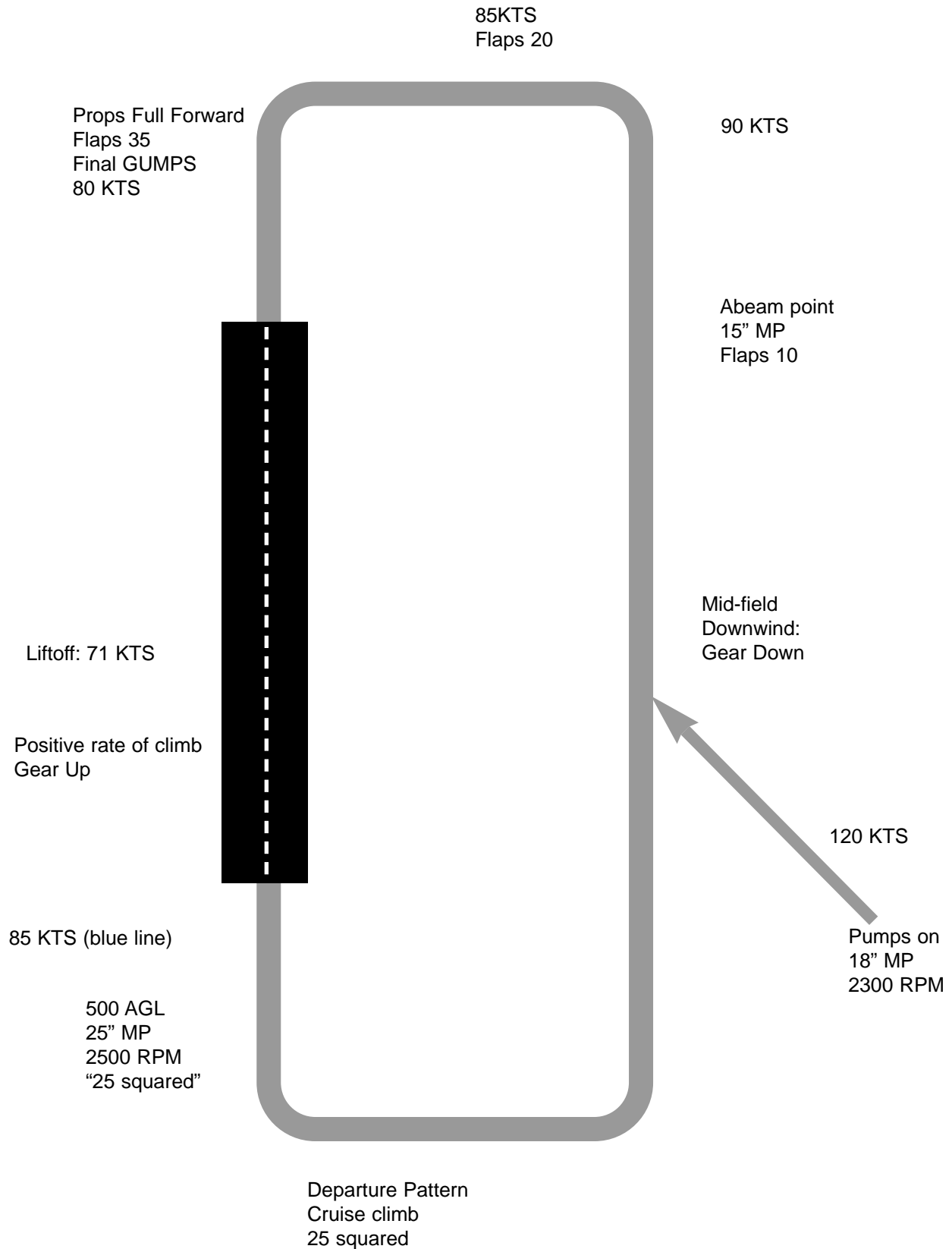
## Landing Gear System

- Can be totally hydraulic (engine driven hydraulic pump), totally electric, or an electrically driven hydraulic pump.
- Refer to the POH for operation and safety and emergency features.

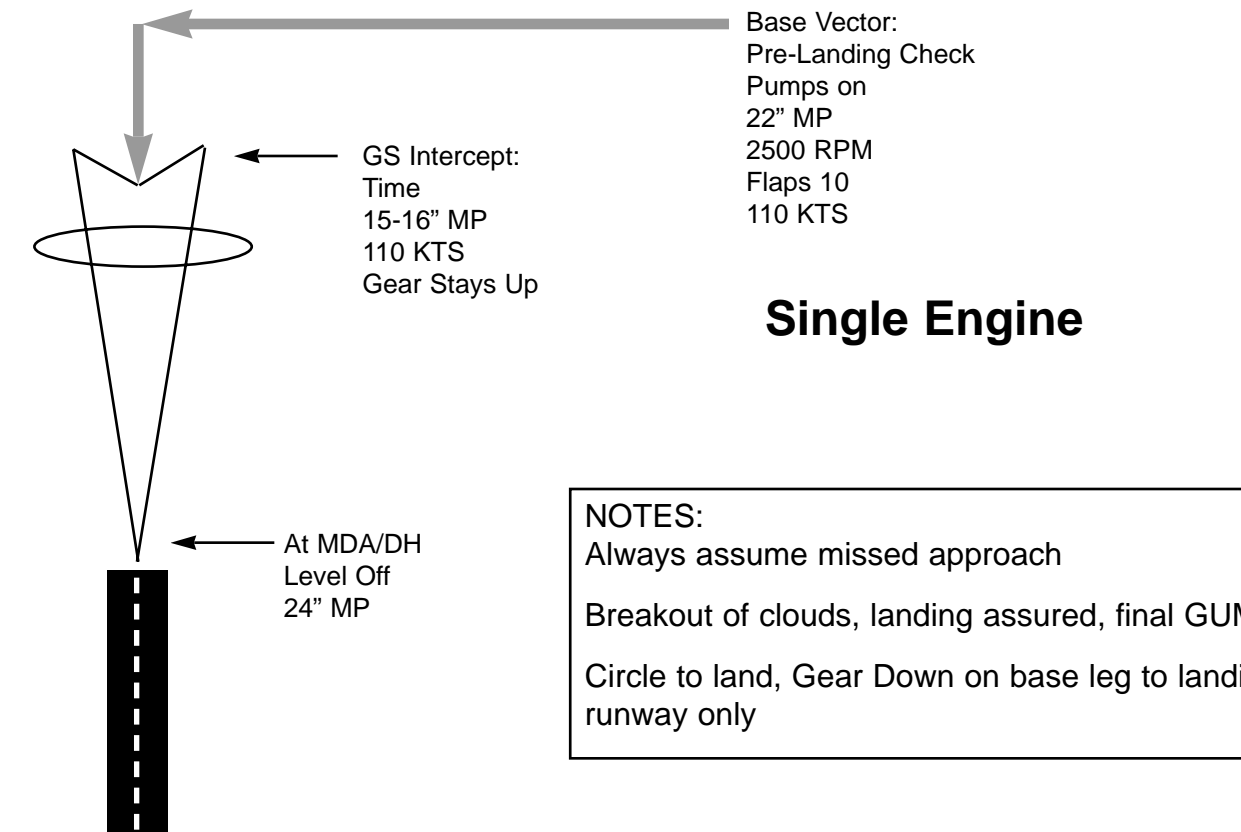
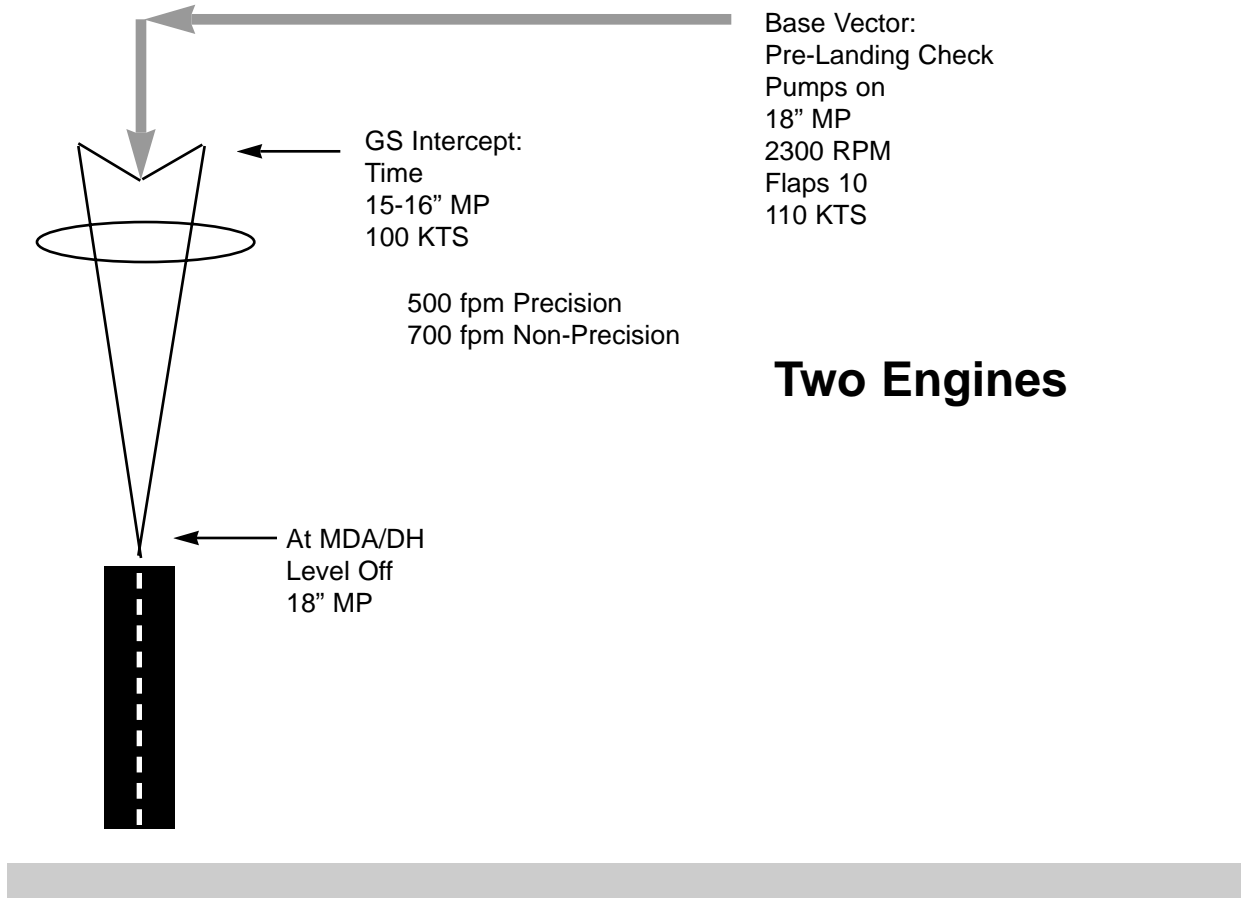
## **BE-76 Airspeeds (KIAS)**

V <sub>so</sub>	60	Stalling speed in the landing configuration or the minimum steady flight speed at which the airplane is controllable (Bottom of white arc)
V <sub>s</sub>	70	Stalling speed in a specified configuration (Bottom of green arc)
V <sub>mc</sub>	65	Minimum flight speed at which the airplane is directionally controllable (Red radial line)
V <sub>lof</sub>	71	Lift off airspeed
V <sub>x</sub>	71	Best angle-of-climb speed, greatest gain in altitude in the shortest possible horizontal distance
V <sub>xse</sub>	85	
V <sub>y</sub>	85	Best rate-of-climb speed, greatest gain in altitude in the shortest possible time (Blue radial--Vyse)
V <sub>yse</sub>	85	
V <sub>l/d</sub>	95	Speed for the best lift-to-drag ratio
V <sub>fe</sub>	110	Maximum flap extended speed, highest speed permissible with wing flaps in a prescribed extended position (Top of white arc)
V <sub>a</sub>	132	Maneuvering speed, maximum speed at which application of full available aerodynamic control will not over-stress the airplane
V <sub>lo</sub>	112 up 140 down	Maximum landing gear operating speed, maximum speed at which the landing gear can be safely extended or retracted
V <sub>le</sub>	140	Maximum landing gear extended speed, maximum speed at which an airplane can be safely flown with the landing gear extended
V <sub>no</sub>	154	Maximum structural cruising speed is the speed that should not be exceeded except in smooth air and then only with caution
V <sub>ne</sub>	194	Never exceed speed is the speed limit that may not be exceeded at any time

# BE76 Normal Traffic Pattern

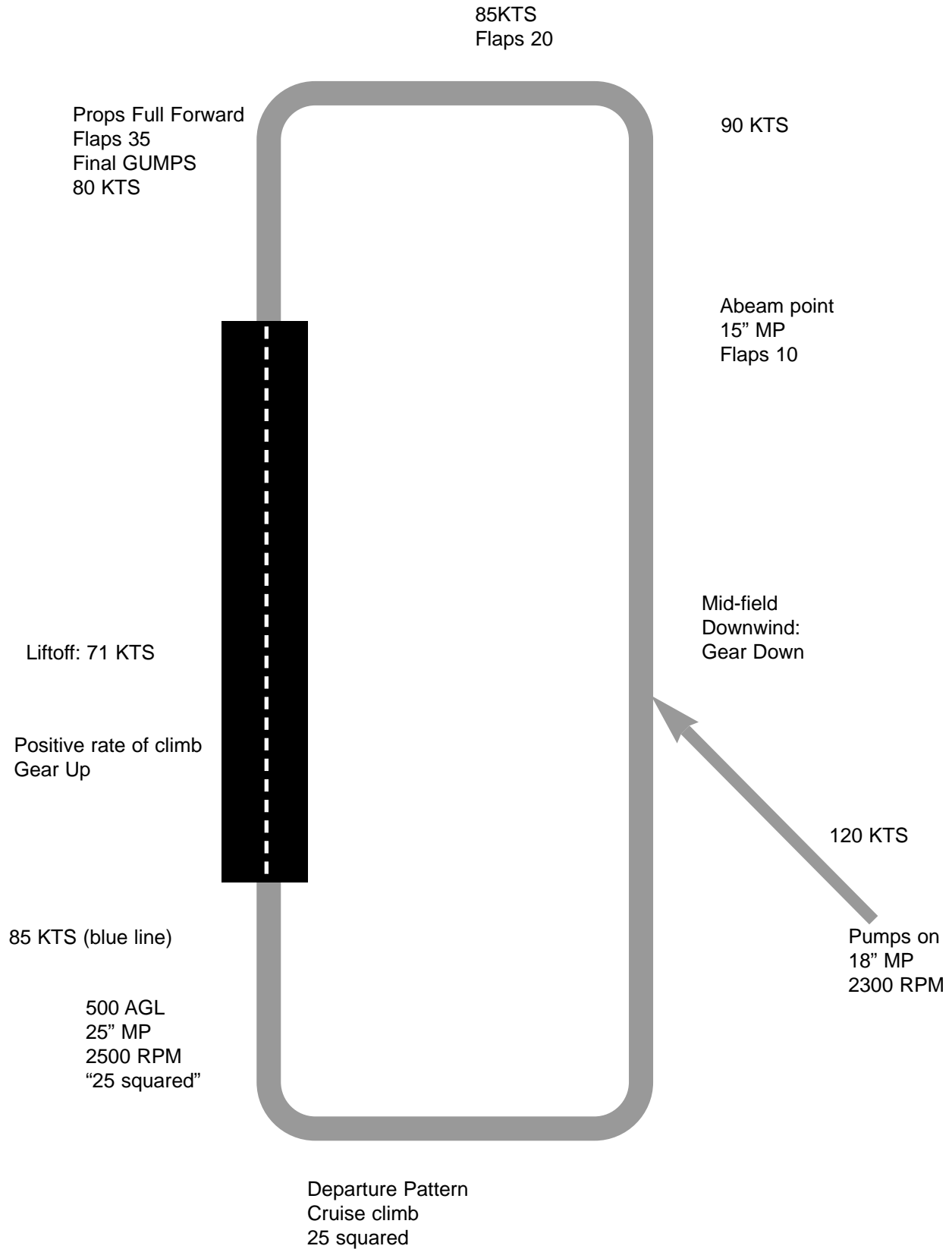


# BE76 Approach Procedures



**NOTES:**  
Always assume missed approach  
Breakout of clouds, landing assured, final GUMPS  
Circle to land, Gear Down on base leg to landing runway only

# BE76 Normal Traffic Pattern



# **BE-76 Normal Procedures**

## **Vmc Demo & Power On Stalls**

Clearing Turn - Complete  
Throttles - 15" Manifold Pressure  
Aux Pumps - On  
Gas - On  
Cowl Flaps - Open  
Carb Heat - Cold  
Mixtures - Rich  
100 KIAS - Props Forward

## **Power on Stall**

At 85 KIAS  
Pitch up to 20°  
Throttles - Full  
At First Sign of Stall - Recover  
Lower Pitch Slightly  
Level Off  
Back to Slow Cruise

## **Vmc Demo**

One Throttle to Idle  
One Throttle Full Open  
Maintain 85 KIAS  
Pitch to Lose 1KT/second

At Loss of Directional Control  
Lower the Nose  
Good Engine to Idle  
Regain Control & Airspeed  
Power Up Good Engine  
Pitch for 85 KIAS

# **BE-76 Normal Procedures**

All maneuvers start from slow cruise  
(20 inches manifold pressure and 2300 RPM)

Note: It is acceptable practice to put in 20° of flaps below 120 KIAS.

## **Slow Flight & Power Off Stall**

Clearing Turns - Complete  
Throttles 15" Manifold Pressure  
Gear Down (Below 140 KIAS)  
Aux Pumps - On  
Gas - On  
Cowl Flaps - Open  
Carb Heat - Off  
Flaps - 120 KIAS - 10° to 20°  
110 KIAS - Flaps to Full  
Mixture Rich  
85 KIAS - Props Forward

## **Power Off Stall**

Power - Smoothly Back to Idle  
Pitch - Slowly Increase  
At First Sign of Stall - Recover  
Power - Full  
Pitch - Lower Nose  
Flaps Up  
Pitch For 85 KIAS  
Positive Rate - Gear Up  
Level Off  
Back to Slow Cruise

## **Slow Flight**

Maintain 71 KIAS  
Power as Required (16-18")  
Recovery:  
Power - Full  
Flaps - Up  
Gear - Up  
Back to Slow Cruise

# BE-76 Procedures

## Normal Approach and Landing

Downwind:

1) Power to 18" 2300 RPM - 120 KIAS

2) Prelanding checklist

(GUMPFS)

Gas -- selectors, pumps, pressure

Undercarriage -- gear down, "three in green"

Mixtures -- full rich

Props -- yet to go

Flaps -- 10 -

Seat Belts and Switches -- on

Abeam:

1) Throttle to 15"

2) Flaps to 10 (if not already)

3) Glide at 90 KIAS

Base:

1) Second GUMPFS check

2) Flaps to 20

3) Glide at 85 KIAS (blue line on base)

Final:

1) Final GUMPFS check

2) Props full forward

3) Flaps to 35 with runway made

4) Glide at 80 KIAS, 76 KIAS short final

## Single Engine Approach and Landing

Downwind:

1) Power to 22"-24" 2500 RPM - 120 KIAS

2) Prelanding checklist (GUMPFS)

-Same as above except GEAR STAYS UP!

Abeam:

1) Throttle to 15"

2) Flaps to 10 (if not already)

3) Glide at 95 KIAS

Base:

1) Second GUMPFS check

2) Flaps to 20

3) Glide at 90 KIAS

Final:

1) Final GUMPFS check

2) Props full forward

3) Flaps to 35 with runway made

4) Glide at 85 KIAS, 80 KIAS short final

## Go Around Procedures (Normal)

1) Power up (mixture, prop, throttle)

2) Flaps retract

3) Establish Vy attitude (85 KIAS)

4) Positive rate of climb - GEAR UP

## Single-Engine Go-Around Procedures

1) Power up (mixture, prop, throttle)

2) Flaps retract to 0

3) Positive rate of climb - Gear Up

4) Establish Vyse

NOTE: In the BE-76, after full flaps are selected on a single engine approach, GO-AROUND is no longer an option.

## Instrument Approach Procedures

### Normal Procedures:

1) Prelanding checklist complete prior to FAF or OM

2) When 90 degrees to inbound final approach course, configure for the approach: 18", 2300 RPM, 10 flaps = 110 KIAS

3) FAF or OM inbound: 14" - 17", gear down = 100 KIAS

4) 18" to level off at the MDA

### Single Engine Procedures:

1) Prelanding checklist complete prior to FAF or OM

2) When 90 degrees to inbound final approach course, configure for the approach: 22" - 24", 2500 RPM, 10 flaps = 110 KIAS

3) FAF or OM inbound: 13" - 15", gear stays up = 100 KIAS

4) 24" to level off at the MDA

NOTE: After breaking out of clouds and landing is assured, final GUMPFS for gear, props, and flaps

# BE-76 Systems

## Engines

Two direct drive, 4 cylinder, horizontally opposed, normally aspirated engines by Avco Lycoming.

Left engine: O-360 (prop turns clockwise)  
Right engine: LO-360 (prop turns counterclockwise)  
Both are rated at 180 horsepower at 2700 RPM

## Propellers

Two Hartzell, 76" diameter, constant-speed, full feathering, two bladed props. Prop RPM is controlled by an engine driven prop governor which regulates hydraulic oil pressure to the hub.

High RPM/Low pitch: Engine oil under governor boosted pressure; if oil pressure to the hub is lost, the prop will want to go to a full feathered position.

Low RPM/High pitch: Springs and dome air pressure aided by counterweights

Note: Both of St. Charles' aircraft are equipped with unfeathering accumulators.

## Pressure System

Two, engine-driven, dry, pressure pumps supply air pressure to drive the attitude and directional gyro instruments, and autopilot. The pumps are interconnected to form a single system. Check valves automatically close if either pump fails to ensure continued gyro operation.

## Fuel System

Designed for 100 octane (green) or 100LL(blue).

Fuel is drawn from the tank through a strainer to a fuel selector valve. It then passes through a check valve to the engine driven fuel pump and delivered to the carburetor.

Crossfeed allows pilot to choose which tank an engine will feed from. Used to maintain lateral stability/balance during extended single engine operation. Should only be used in level flight.

Capacity: Two main tanks holding 103 gallons total, 100 gallons usable (50 gallons usable per tank)

Drains: 8 total; 4 on each wing (1) tank, (1) fuel selector, (2) crossfeed lines

Pumps: 2 engine driven, 2 electrically driven aux pumps

A 45,000 BTU-per-hour Janitrol gas combustion cabin heater, located in the right side of the nose compartment, burns approximately 2/3 gallon per hour from the right wing tank only.

## Oil System

Each engine equipped with a wet-sump, pressure-type oil system. Sump capacity is 8 quarts per engine.

## Stall Warning

A sensing vane is installed on the leading edge of each wing.

Left wing: horn triggered when flaps are 0-16 degrees

Right wing: horn triggered when flaps are 17-35 degrees

# BE-76 Systems

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# Flying Light Twins Safely

The major difference between flying a twin-engine and a single-engine airplane is knowing how to manage the flight if one engine loses power for any reason. Safe flight with one engine out requires an understanding of the basic aerodynamics involved— as well as proficiency in engine-out procedures.

## Loss of Power on One Side

Loss of power from one engine affects both climb performance and controllability of any light twin.

## Climb Performance

Climb performance depends on an excess of power over that required for level flight. Loss of power from one engine obviously represents a 50% loss of power but, in virtually all light twins, climb performance is reduced by at least 80%.

The amount of power required for level flight depends on how much drag must be "overcome" to sustain level flight. It's obvious, that if drag is increased because the gear and flaps are down and the prop windmilling, more power will be required. Not so obvious, however, is the fact that drag also increases as the square of the air-speed while power required to maintain that speed increases as the cube of the airspeed.

Thus, climb performance depends on four factors:

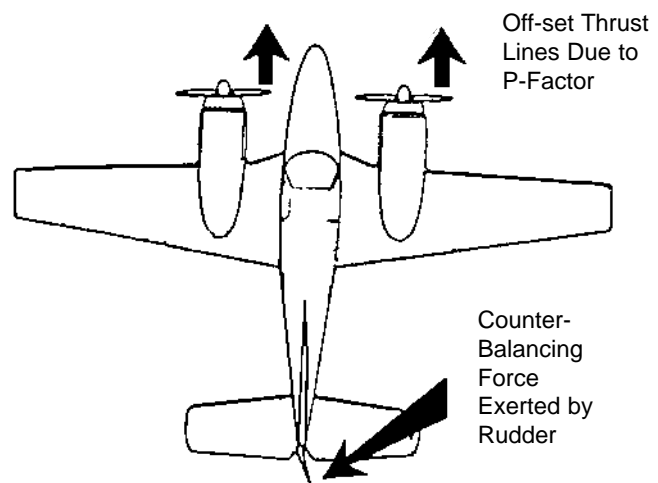
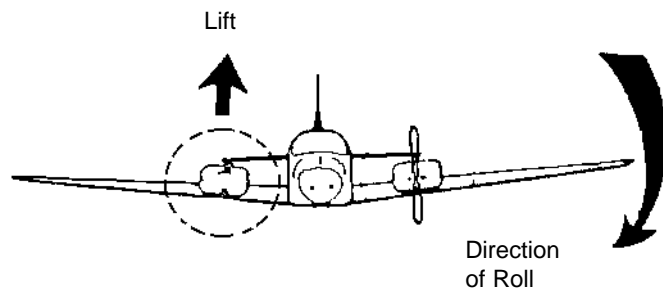
- Airspeed—too little or too much will decrease climb performance.
- Drag —gear, flaps, cowl flaps, prop and speed.
- Power —amount available in excess of that needed for level flight.
- Weight —passengers, baggage and fuel load greatly affect climb performance.

## Yaw

Loss of power on one engine also creates yaw due to asymmetrical thrust. Yaw forces must be balanced with the rudder.

## Roll

Loss of power on one engine reduces prop wash over the wing. Yaw also affects the lift distribution over the wing causing a roll toward the "dead" engine. These roll forces may be balanced by banking into the operating engine.



# Flying Light Twins Safely

## Critical Engine

The critical engine is that engine whose failure would most adversely affect the performance or handling qualities of the airplane. The critical engine on most U.S. light twins is the left engine as its failure requires the most rudder force to overcome yaw. At cruise, the thrust line of each engine is through the propeller hub.

But, at low airspeeds and at high angles of attack, the effective thrust centerline shifts to the right on each engine because the descending propeller blades produce more thrust than the ascending blades (P-factor). Thus, the right engine produces the greatest mechanical yawing moment and requires the most rudder to counterbalance the yaw.

## Key Airspeed for Single Engine Operations

Airspeed is the key to safe single engine operations. For most light twins there is an

- Vmca • airspeed below which directional control cannot be maintained.
- Vsse • airspeed below which an intentional engine cut should never be made.
- Vyse • airspeed that will give the best single engine rate-of-climb (or the slowest loss of altitude).
- Vxse • airspeed that will give the steepest angle of climb with one engine-out.

## Minimum Control Speed Airborne (Vmca )

Vmca is designated by the red radial on the airspeed indicator and indicates the minimum control speed, airborne at sea level. Vmca is determined by the manufacturer as the minimum airspeed at which it is possible to recover

directional control of the airplane within 20 degrees heading change and, thereafter, maintain straight flight, with not more than 5 degrees of bank if one engine fails suddenly with:

- Take-off power on both engines,
- Rearmost allowable center of gravity,
- Flaps in takeoff position,
- Landing gear retracted,
- Propeller wind milling in takeoff pitch configuration (or feathered if automatically featherable).

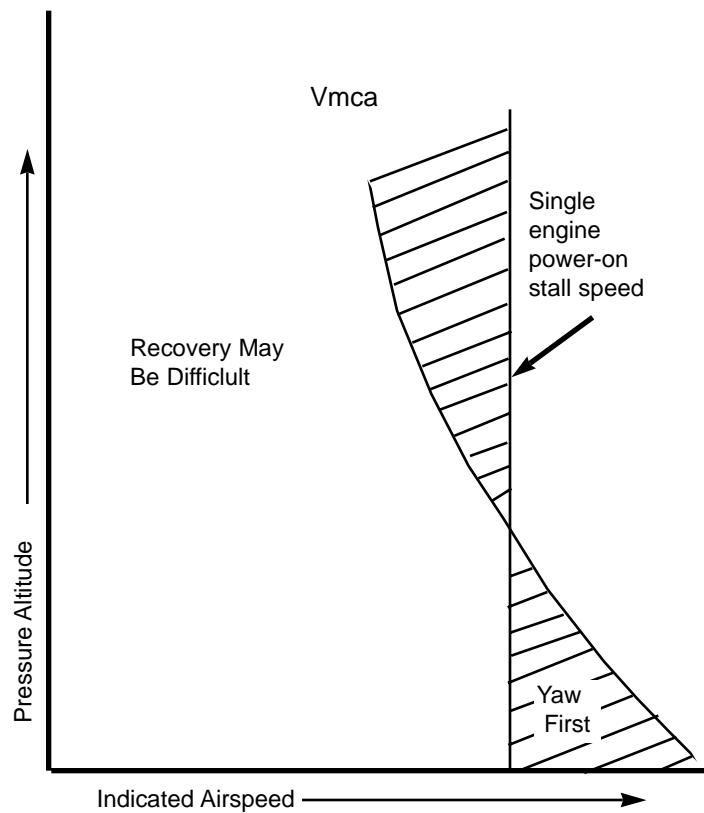
However, sudden engine failures rarely occur with all of the factors listed above and, therefore, the actual Vmca under any particular situation may be a little slower than the red radial on the airspeed indicator. However, most airplanes will not maintain level flight at speeds at or near Vmca. Consequently, it is not advisable to fly at speeds approaching Vmca except in training situations or during flight tests.

## Intentional One-Engine Inoperative Speed (Vsse )

Vsse is specified by the airplane manufacturer in new Handbooks and is the minimum speed at which to perform intentional engine cuts. Use of Vsse is intended to reduce the accident potential from loss of control after engine cuts at or near minimum control speed. Vmca demonstrations are necessary in training but should only be made at a safe altitude above the terrain and with the power reduction on one engine made at or above Vsse. Power on the operating (good) engine should then be set at the position for maximum continuous operation. Airspeed is reduced slowly (one knot per second) until directional control can no longer be maintained or the first indication of a stall obtained.

Recovery from flight below Vmca is made by reducing power to idle on the operating (good)

## Flying Light Twins Safely



engine, decreasing the angle of attack by dropping the nose, accelerating through  $V_{mca}$ , and then returning power to the operating engine and accelerating to  $V_{yse}$ , the blue radial speed.

### Best Single Engine Rate-of-Climb Speed ( $V_{yse}$ .)

$V_{yse}$  is designated by the blue radial on the airspeed indicator.  $V_{yse}$  delivers the greatest gain in altitude in the shortest possible time, and is based on the following criteria:

- critical engine inoperative, and its propeller in the minimum drag position.
- operating engine set at not more than maximum continuous power.
- Landing gear retracted.
- wing flaps in the most favorable (i.e., best

lift/drag ratio position.

- cowl flaps as required for engine cooling.
- airplane flown at recommended bank angle.

Drag caused by a windmilling propeller, extended landing gear, or flaps in the landing position will severely degrade or destroy single engine climb performance. Single engine climb performance varies widely with type of airplane, weight, temperature, altitude and airplane configuration. The climb gradient (altitude gain or loss per mile) may be marginal— or even negative—under some conditions. Study the Pilot's Operating Handbook for your specific airplane and know what performance to expect with one engine out. Remember, the Federal Aviation Regulations do not require any single engine climb performance for light twins that weigh 6000 pounds or less and that have a stall speed of 61 knots or less.

# Flying Light Twins Safely

## Best Single Engine Angle-of-Climb Airspeed ( $V_{xse}$ )

$V_{xse}$  is used only to clear obstructions during initial climb-out as it gives the greatest altitude gain per unit of horizontal distance. It provides less engine cooling and requires more rudder control than  $V_y$ .

## Single Engine Service Ceiling

The single engine service ceiling is the maximum altitude at which an airplane will climb, at a rate of at least 50 feet per minute in smooth air, with one engine feathered. New Handbooks show service ceiling as a function of weight, pressure altitude and temperature while the old Flight Manuals frequently use density altitude.

The single engine service ceiling chart should be used during flight planning to determine whether the airplane, as loaded, can maintain the Minimum Enroute Altitude (MEA) if IFR, or terrain clearance if VFR, following an engine failure.

## Basic Single-Engine Procedures

Know and follow, to the letter, the single-engine emergency procedures specified in your Pilot's Operating Handbook for your specific make and model airplane. However, the basic fundamentals of all the procedures are as follows:

- Maintain aircraft control and airspeed at all times. This is cardinal rule No. 1.
- Usually, apply maximum power to the operating engine. However, if the engine failure occurs during cruise or in a steep turn, you

may elect to use only enough power to maintain a safe speed and altitude. If the failure occurs on final approach, use power only as necessary to complete the landing.

- Reduce drag to an absolute minimum.
- Secure the failed engine and related sub-systems.

The first three steps should be done promptly and from memory. The check list should then be consulted to be sure that the inoperative engine is secured properly And that the appropriate switches are placed in the correct position. The airplane must be banked into the live engine with the "slip/skid" ball out of center toward the live engine to achieve Handbook performance.

Another note of caution: Be sure to identify the dead engine, positively, before feathering it. Many red faced pilots both students and veterans alike— have feathered the wrong engine. Don't let it happen to you. Remember: First, identify the suspected engine ("Dead foot means dead engine"); second, verify, with cautious throttle movement; then feather. But be sure it is dead and not just sick.

## Engine Failure - General Procedures

- Power up (right to left)
  - mixture up
  - props up
  - throttles up
- Clean up (right to left)
  - flaps up
  - gear up
  - aux fuel pumps on
- Identify
  - "Dead foot, dead engine"
- Verify
  - cautiously retard throttle
- Rectify
  - checklist for possible restart if conditions permit
- Secure
  - feather prop
  - mixture idle cut-off
  - see checklist

# Flying Light Twins Safely

## Engine Failure on Takeoff

If an engine fails before attaining liftoff speed, the only proper action is to discontinue the takeoff. If the engine fails after liftoff with the landing gear still down, the takeoff should still be discontinued if touch-down and roll-out on the remaining runway is still possible.

If you do find yourself in a position of not being able to climb, it's much better to pull the power on the good engine and land straight ahead than try to force a climb and lose control.

Pilot's Operating Handbooks have charts that are used in calculating the runway length required if the engine fails before reaching liftoff speed and may have charts showing performance after liftoff such as:

- Accelerate-Stop Distance. That's the distance required to accelerate to liftoff speed and, assuming failure to engine at the instant that liftoff speed is attained, to bring the airplane to a full stop.
- Accelerate-Go Distance. That's the distance required to accelerate to liftoff speed and, assuming failure of an engine at the instant liftoff speed is attained, to continue the take-off on the remaining engine to a height of 50 feet.

Study your accelerate-go charts carefully. No airplane is capable of climbing out on one engine under all - weight, pressure altitude and temperature conditions. Know, before you take the actual runway, whether you can maintain control and climb-out if you lose an engine while; the gear is still down. It may be necessary to off-load some weight, or wait for more favorable temperature or wind conditions.

## When to Fly $V_x$ , $V_y$ , $V_{xse}$ and $V_{yse}$

During normal two-engine operations, always fly  $V_y$  (or  $V_x$  if necessary for obstacle clearance) on initial climb-out. Then, accelerate to your cruise climb airspeed, which may be  $V_y$  plus 10 to 15 knots after you have obtained a safe altitude. Use of cruise climb airspeed will

give you better engine cooling, increased inflight visibility and better fuel economy. However, at the first indication of an engine failure during climb-out, or while on approach, establish  $V_{yse}$  or  $V_{xse}$  whichever is appropriate. (Consult your Handbook or Flight Manual for specifics.)

## Summary

Know the key airspeeds for your airplane and when to use them:

$V_{mc}$  (Red Radial) never fly at or near this airspeed except in training or during flight test situations.

$V_{sse}$  never intentionally cut an engine below this airspeed.

$V_{yse}$  (Blue Radial) always fly this airspeed during a single engine emergency during climb-out except when necessary to clear an obstacle after takeoff and on final approach until committed for landing.

$V_{xse}$ —Fly  $V_{xse}$  to clear obstacles, then accelerate to  $V_{yse}$

Know the performance limitations of your airplane, including its:

- accelerate-stop distances,
- accelerate-go distances,
- single engine service ceiling, and
- maximum weight for which single engine climb is possible.

Know the basic single engine emergency procedures:

- Maintain control of the airplane by flying at the proper airspeed.
- Apply maximum power, if appropriate.
- Reduce drag (includes feathering).
- Complete engine-out checklist.

And finally, put your knowledge into practice with a qualified instructor pilot observing and assisting you. Engine failures can be handled competently and safely by proficient pilots. Keep your proficiency up and every flight in a multi-engine airplane should be a safe one.

# Always Leave Yourself An Out

Despite heated scoldings from flight instructors and grim warnings from the National Transportation Safety Board, many pilots still seem to believe that implied in the fact that an aircraft has two engines is a promise that it will perform with only one of those engines operative. And the light twin stall/spin accident rate further indicates that many multi-engine pilots have not come to grips with the facts that

1. Significantly more than half the climb performance disappears when one engine signs out, and
2. Exploration of the  $V_{mc}$  regime close to the ground is a sure way to kill yourself.

A while back, the NTSB reported that light multi-engine aircraft are involved in fewer engine failure related accidents than single engine aircraft. However the same report observed that an engine failure related accident in a twin is four times more likely to cause serious or fatal injuries.

This article is not intended to debate the relative merits of twins versus singles. The twin offers obvious safety advantages over the single, especially in the enroute phase, and if, and only if, the pilot fully understands the real options offered by that second engine in the takeoff and approach phases as well.

Takeoff is the most critical time for a light twin pilot, but if something goes wrong he may have the option of continued flight, an option denied his single engine counterpart. More often than not that second engine will provide only a little more time to pick a soft spot. (This assumes that the engine is lost before the aircraft reaches maneuvering altitude of 300 to 500 feet.) But even those few extra seconds, representing a few hundred extra yards, can give the twin pilot a hell of a safety advantage over his single-engine counterpart. But I must stress again, this safety advantage exists only if the multi-engine pilot fully understands his machine.

In this article we're going to explore some of the design concepts and certification procedures applicable to current-production light twins and then take a look at light twin performance tables and attempt to find ways of getting more realistic information out of them. Along the way, we'll establish five rules for technique. We use these rules at B/CA, pilots at the FAA Academy use them, and we're sure many readers are aware of them, but we'll throw them in anyway in hopes of picking up a few more converts.

Let's look first at the implied promise that a general aviation twin will perform with one engine inoperative. Part 23 sets standards for the certification of light aircraft weighing 12,500 pounds or less. Multi-engine aircraft are further divided by Part 23 into two weight classes, split at 6,000 pounds with the group that weighs 6,000 pounds or less, subdivided into two, depending on  $V_{so}$  (stall speed in the landing configuration). The break comes at 61 knots CAS.

Only those twins that weigh more than 6,000 pounds or have a  $V_{so}$  higher than 61 knots need to demonstrate any single-engine climb performance at all for certification. And the requirement is pretty meager. Basically, the regulation says that these aircraft must demonstrate a single-engine climb capability at 5,000 feet (ISA) with the inoperative engine feathered and the aircraft in a clean configuration. The amount of climb performance required is determined by the formula  $ROC=0.027 V_{so}^2$ . The Rockwell Commander 500S (Shrike), for example, weighs over 6,000 pounds and therefore must meet this climb requirement.  $V_{so}$  for the Shrike is 63 knots, thus its minimum single-engine climb performance at 5,000 feet is  $0.027 \times 63^2$  or 107.16 fpm. The Shrike's actual single-engine climb at 5,000 feet is 129 fpm, so the manufacturer bettered the Part 23 requirement, but not by much.

The Cessna 310 weighs less than 6,000 pounds, but stalls at 63.9 knots, so it too must meet the enroute single-engine climb standards. Plugging 63.9 knots into the  $0.027 V_{so}^2$

## Always Leave Yourself An Out

equation produces a requirement of 110.2 fpm. The 310's actual single-engine climb under Part 23 conditions is 119 fpm.

The Aztec, like the 310, weighs less than 6,000 pounds, but it slips under the V<sub>so</sub> wire with a stall speed of 60.8 knots. The only requirement that an airplane in this group must meet is that its single-engine climb performance at 5,000 feet (positive or negative) be determined. The Aztec climbs at 50 fpm on one engine at that altitude, but the regulation doesn't require that it climb at all at that or any other altitude.

We can see then that where an enroute single-engine climb is required, it's minimal. Consider a hypothetical aircraft with an outrageous V<sub>so</sub> of 100 knots CAS. The FAA requires only that such an aircraft demonstrate a paltry climb of 270 fpm on one engine at 5,000 feet.

There's another point to consider here. The FAA does not require continued single-engine takeoff capability for any light aircraft other than those designed for air-taxi work and capable of hauling 10 or more passengers. Stated another way, there is no reason to assume that an aircraft will exhibit positive single-engine performance in the takeoff configuration at sea level just because it had to meet a single-engine climb-performance requirement at 5,000 clean.

FAA Academy flight instructors are fully aware of this situation and believe it's important to stress it with the agency's GADO inspectors. An in-house white paper on light twins used at training courses for FAA pilots puts it this way:

"There is nothing in the FAR governing the certification of light multi-engine aircraft which says they must fly (maintain altitude) while in the takeoff configuration and with an engine inoperative. In fact, many of the light twins are not required to do this with one engine inoperative in any configuration, even at sea level. With regard to performance (but not controllability) in the takeoff or landing configuration, the light multi-engine aircraft is, in concept, merely a single-engine aircraft with its power divided into two or more individual packages."

While this concept of not putting all your

eggs in one basket leads to certain advantages, it also leads to disadvantages should the eggs in one basket get broken.

You'll remember from your multi-engine transition training that the flight instructor and check pilot repeatedly insisted that when you lose one engine on a twin, performance is not halved, but actually reduced by 80 percent or more.

That 80-percent performance-loss figure is not just a number pulled out of the air for emphasis. It's easy to figure for any aircraft. Consider the Beech Baron B55 which has an all-engine climb rate (sea level, standard conditions, max gross weight) of 1,670 fpm and a single-engine climb rate under the same conditions of 318 fpm. The loss of climb performance in this case is

$$100 - ( 318 / 1670 \times 100 )$$

or 80.96 percent. The climb performance remaining after the loss of one engine on the B55 is 19.04%.

Performance loss for the cabin twins, turboprops and business jets is similar. The Rockwell Commander 685, for example, loses 83.42% of its climb performance when one engine quits; the Swearingen Merlin III loses 75.49% and the Learjet 25C 71.07%. The Lockheed JetStar loses 43.48% if its climb performance with the loss of one engine, but remember, it has four engines. The loss of one quarter of its thrust results in a loss of almost half its climb performance and if it were to lose half its thrust, climb performance would be cut by more than 75%. (The table on this page shows similar performance changes for other aircraft.)

Some turboprops and all turbojets demonstrate a continued takeoff capability with one engine inoperative. The turbojets do so because of the tougher certification requirements of FAR Part 25. Although loss of power in terms of percentage reduction is similar in all categories of business aircraft the turbojets and some turboprops have much better single-engine performance because they're starting with higher numbers. While the Learjet 25C, for example,

## Always Leave Yourself An Out

loses more than 71% of its climb performance when an engine is shut down, it begins with an engine rate of climb of 6,050 fpm. When this reduced by 71%, it still climbs at 1,750 which is much better performance than you get out of many light-piston twins with both engines running.

Why the performance loss is greater than 50% with the failure of one engine needs bit of explanation. Climb performance is a function of thrust horsepower (or simply thrust in turbojets) which is in excess of that required for straight and level flight. You can convince yourself that this is the case by trimming your aircraft for straight and level at its best all engine rate-of-climb speed and checking the power setting. If you ease the stick back at that point, the airplane will not settle into a sustained climb. After a momentary climb it may in fact, begin to descend. However, if you go back to straight and level flight at the best-rate-of-climb speed and slowly feed in power as you maintain airspeed, a climb will be indicated and the rate of climb will depend on the power you add—which is power in excess of that, required for straight and level.

Now trim for straight and level (in the clean configuration at about 1,500 feet) at the best single-engine rate-of-climb speed, adjust engine to its zero-thrust setting (about 1 inches to simulate feather). You'll notice that the "good" engine, now carrying the full burden, is producing 75-percent power or more. If you increase the power on the good engine your aircraft will begin a climb, but at a very modest rate. This is so because you've got much less "excess" horsepower available.

you are interested in the math behind this, a approximate formula for rate of climb is:

$$R/C = \text{ehp} \times 33,000 \text{ weight}$$

(ehp is thrust horsepower in excess of that required for straight and level.) To determine ehp, rearrange the formula to read:

$$\text{ehp} = R/C \times \text{weight} / 33,000$$

Using the Seneca as an example, with its maximum gross weight of 4,200 pounds and all engine and single-engine climb rates of 1,860 and 190 fpm respectively, we find that this aircraft has about 236 thrust horsepower available for climb with both powerplants operating and only 24 excess thrust horsepower for climb on one engine. If you refer to the climb-performance-loss formula, you'll see that the Seneca loses about 89.78% of its climb performance when an engine stops:

$$100 - 190/1860 \times 100 = 89.78$$

If you examine the two figures above for excess horsepower and state them in terms of percentages, you'll see that an engine loss in the Seneca represents a loss of 89.83 percent of thrust horsepower available for climb.

Part 23 defines Vmc as "the minimum calibrated airspeed at which, when any engine is suddenly made inoperative, it is possible to recover control of the airplane with that engine still inoperative, and maintain straight flight, either with zero yaw, or, at the option of the manufacturer, with an angle of bank of not more than five degrees." Vmc may not be higher than 1.2 times the stall speed with flaps in takeoff position and the gear retracted. In flight-test work, Vmc is determined with takeoff or METO power on each engine, the rearmost allowable center of gravity, flaps in takeoff position, landing gear retracted and the propeller of the inoperative engine

1. Windmilling with the propeller set in the takeoff range, or
2. Feathered, if the airplane has an automatic feathering device.

During recovery, the airplane may not assume any dangerous attitude or require exceptional piloting skill, alertness, or strength to prevent a heading change of more than 20 degrees.

Vmc is not at all mysterious. It's simply that speed at which airflow past the rudder is reduced to such an extent that rudder forces cannot overcome the asymmetrical forces

# Always Leave Yourself An Out

## Performance Loss of Representative Twins with One Engine Out

	All engine climb (fpm)	SE climb (fpm)	Percent Loss
<b>Pistons</b>			
Beech Baron 58	1,694	382	80.70
Beech Duke	1,601	307	80.82
Beech Queen Air	1,275	210	83.53
Cessna 310	1,495	327	78.13
Cessna 340	1,500	250	83.33
Cessna 402B	1,610	225	86.02
Cessna 421B	1,850	305	83.51
Piper Aztec	1,490	240	83.89
Piper Navajo Chieftain	1,390	230	83.45
Piper Pressurized Navajo	1,740	240	86.21
Piper Seneca	1,860	190	89.78
<b>Turboprops</b>			
Beech King Air 90	1,870	470	74.87
Mitsubishi MU2-J	2,690	845	68.59
Rockwell Commander 690A	2,849	893	68.66
Swearinger Merlin 111	2,530	620	75.49
<b>Business Jets</b>			
Cessna Citation	3,100	800	74.19
Falcon F	3,300	800	75.76
Falcon 10	6,000	1,500	75.00
Gates Learjet 24D	6,800	2,100	69.12
Grumman Gulfstream 11	4,350	1,525	64.94
Hawker Siddeley HS 125-600	3,550	663	81.32
Westwind	4,040	1,100	72.77
Rockwell Sabre 75A	4,300	1,100	74.42

## Always Leave Yourself An Out

caused by takeoff power on one side and a windmilling prop on the other.

When that speed is reached and the nose starts to swing toward the inoperative engine, the only hope of regaining control is to reduce thrust on the good engine (or increase speed). An increase in airspeed requires a change in momentum and thus a certain period of time to become effective. Thus, for practical purposes, the on/y method of regaining control is to reduce power on the operating engine—quickly.

V<sub>mc</sub> is not a static number like flap operating speed or the never exceed speed. It changes with conditions. The Part 23 test described above cites the worst conditions. Aft CG, for example, reduces the force of the rudder because it shortens the arm and thus the turning moment. V<sub>mc</sub> will be lower with forward CG and all other factors being equal.

Conversely if the aircraft is loaded slightly out of rear CG, V<sub>mc</sub> will be higher. In normally aspirated aircraft V<sub>mc</sub> decreases with an increase in density altitude primarily because the output of the operating engine decreases, thus the asymmetrical power situation decreases.

At first glance, this situation seems to be a good one. The hotter and higher the airport, the lower V<sub>mc</sub>. But actually nothing about V<sub>mc</sub> is good and there's a hell of a catch in it. As V<sub>mc</sub> decreases (with a decrease in good-engine performance) it approaches the stall speed. This is especially bad news for flight instructors who must purposely explore the V<sub>mc</sub> regime with their students. If V<sub>mc</sub> and stall are reached simultaneously, a spin is almost inevitable and Part 23 twins are often impossible to get out of a spin. (One northeast flight school lost two aircraft in one summer because of this problem.)

Landing-gear extension seems to reduce:

V<sub>mc</sub> for most light twins and this, like the density altitude situation, can be both good and bad. Suppose a pilot gets himself in the unhappy situation of being 50 feet in the air, gear down, with one engine out, full power on the

good side and full rudder to keep the nose from swinging. He doesn't like the look of the trees in front of him so he decides to make a go for it. He reaches down and retracts the gear to get rid of its drag, hoping that will enable the aircraft to accelerate to a climb speed. Suddenly he's looking at the trees through the top of the windshield. Why? Because he was on the edge of V<sub>mc</sub> and sucked up the gear, which increased V<sub>mc</sub> costing him control of the aircraft.

The prudent light-twin pilot, of course, would never find himself in that situation because he would know beforehand that his hopes of accelerating without altitude loss from V<sub>mc</sub> to V<sub>xse</sub> or V<sub>yse</sub> are practically nil.

If your aircraft is relatively new, V<sub>mc</sub>, as determined by the Part 23 certification test, is marked by a red line on the airspeed-indicator face. Indicated V<sub>mc</sub> will never be higher than this line, so the slash can be used as a guide to keep you out of trouble. This does not mean that the airplane will spin out as soon as the line is reached. Under the circumstances described above (such as high density altitude) controlled flight with full power on the operative engine is possible when the indicated airspeed falls below the red line, but it certainly isn't advisable. Exploring this part of the flight envelope in an actual emergency can (and probably will) kill you. So let's establish our first rule for multi-engine flying.

Rule #1—Never allow the airspeed to drop below published V<sub>mc</sub> except during the last few yards of the landing flare, and then only if the field is extremely short.

Some aircraft have an all-engine best-angle-of-climb speed (V<sub>x</sub>) below V<sub>mc</sub>. Using that climb speed under any circumstances can be extremely dangerous. The instructors at the FAA Academy have this to say about the use of V<sub>x</sub> near the ground: "Trying to gain height too fast after takeoff can be dangerous because of control problems. If the airplane is in the air below V<sub>mc</sub> when an engine fails, the pilot might avoid a crash by rapidly retarding the throttles, although the odds are not in favor of the pilot." Thus we have another rule:

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Rule #2—A best all-engine angle-of-climb speed that is lower than Vmc is an emergency speed and should be used near the ground only if you're willing to bet your life that one engine won't quit during the climb.

Manufacturers differ on the proper takeoff speed for a light twin. Piper, for example, recommends that most of its twins be rotated at Vmc. Cessna, on the other hand, suggests liftoff at a speed much higher than Vmc and very close to best single-engine angle-of-climb speed. In the case of the Cessna 310, Vmc is 75 knots, recommended rotation speed is 91 knots and best single-engine angle-of-climb speed is 94.

It's important to note that manufacturers who recommended liftoff at or near Vmc do not, as a rule, show figures for continued takeoff in event of an engine failure at the liftoff speed. The reason is simple. Most Part 23 twins cannot accelerate in the takeoff configuration from Vmc to best single-engine rate-of-climb speed while maintaining a positive climb rule. Conversely it is possible to accelerate them (under near sea-level conditions) from best single-engine angle-of-climb speed to best single-engine rate-of-climb speed while maintaining a positive though meager climb. Manufacturers who recommended liftoff well above Vmc usually show continued single engine takeoff performance in their owners or flight manuals.

Engine-Out Angle of Climb (degrees, at beat-rate speed)

	ISA	ISA + 20		
Piper Seneca	1.2	0.6		
Cessna Skymaster	1.7	1.3		
Piper Turbo Aztec	1.6	1.5		
Cessna 402B	1.2	0.6		
Piper Navajo	1.5	1.1		
Cessna 340	1.4	0.8		
Cessna 421	1.6	1.0		
Rockwell International 685			1.2	0.7
Piper Navajo P	1.2	1.0		
Mitsubishi MU2-K	4.2	2.4		
King Air A100	2.1	1.0		

NOTE: For comparison purposes, the average two engine rate of climb for the above aircraft is 8 degrees.

We have to recommend against lifting off at Vmc for the same reason most flight instructors recommend against "stalling" a single engine aircraft off the ground. In the latter case, the single will fly to the edge of ground effect but could reach that point behind the power curve. An engine failure at that point could result in a stall and pitch over. In the case of the twin, an engine failure at liftoff at Vmc could produce such a rapid turning moment that control would be lost immediately. The FAA says, "Experience has shown that an unexpected engine failure surprises the pilot so that he will act as though he is swimming in glue." If a pilot rotates at Vmc, loses an engine and begins the "swimming in glue" routine, his odds of survival are minimal.

The alternative, of course, is to hold the aircraft on the ground a little longer. Most multi-engine instructors believe that Vmc-plus 5 knots is a good compromise for use in those aircraft with a recommended liftoff at Vmc. Why not hold it down until almost reaching best single-engine angle-of-climb speed like the Cessna folks recommend? The reason again is controllability. Cessna light twins and most cabin twins of all manufacturers are designed to stay on the ground well beyond Vmc. But some of the light twins simply are not. For example, we've tried holding the Seneca and Aztec on the runway beyond Vmc plus-5 knots and have discovered that both aircraft begin to wheelbarrow. (Tests were at maximum gross weight, zero flaps.) High-speed wheelbarrowing can be just as dangerous as liftoff too close to Vmc, especially when we're talking about selecting an appropriate speed for every takeoff. Remember too that the takeoff-performance figures in the aircraft owners or flight manual are invalid as soon as we use techniques different from those specified in the table footnotes. (More on this later.) Anyway, we've got a third rule now for light-twin operation:

Rule #3—Use the manufacturer's recommended liftoff speed or Vmc plus five knots whichever is greater.

Now that we're in the air, the first priority is to accelerate the aircraft to best single-engine

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angle-of-climb speed (if we're not already there), then best single-engine rate-of-climb speed and finally best all-engine rate-of-climb speed. Each of these speeds is a milestone in the takeoff and the realization of each reduces the decisions to be made in the event of an engine failure.

Many instructors recommended that best single-engine rate-of-climb speed (the blue line if it's marked on your airspeed indicator) be used for the initial climb to a safe maneuvering altitude. B/CA's pilots recommended the best all-engine rate-of-climb speed, when it is faster (it normally is), for two reasons. First, the swimming in glue syndrome is going to translate into speed lost. So if an engine does quit while you're holding best all-engine rate-of-climb speed, the deceleration while you're getting things straightened out will probably put you pretty close to best single-engine rate-of-climb speed which is where you want to be anyway. Second, the best all-engine rate speed will get you to maneuvering altitude and out of immediate danger.

One caution here is important. Avoid climbing to maneuvering altitude at a speed greater than best all-engine rate of climb—to do so is sloppy and inefficient. Here's why:

As we have seen, climb is a function of thrust horsepower in excess of that required for straight and level flight and drag increases as the square of the speed. At the same time, power required to maintain a velocity increases as the cube of the velocity.

The Cessna 421 has a best all-engine rate-of-climb speed of 110 knots, which produces a climb of 1,850 fpm at sea level. If the aircraft is climbing at 122 knots, drag would increase by 1.2 times and the power required to maintain that velocity would increase 1.4 times with a resulting decrease of excess thrust horsepower available for climb. In this example the climb rate decreases to about 1,261 fpm; thus a 10-percent increase in speed over the best-rate speed produces a 32-percent decrease in climb performance. These exercises produce another rule:

Rule #4—After leaving the ground above

V<sub>mc</sub>, climb not slower than single-engine best rate-of-climb speed and not faster than best all engine rate of speed. The latter speed is preferable if obstacles are not a consideration.

You may have gotten the impression by now that we're picking on Cessna and Piper in our examples. Piper twins and the Rockwell Commander 500S have shown up in our examples here because the Ziff-Davis Aviation Division operates (or operated in the case of the Shrike) these aircraft and our observations concerning them were gained from extensive first-hand knowledge. The Cessna twins are used as examples because Cessna, in our opinion, produces the best owners manuals in the industry. This is not to say that the Cessna manuals can't be improved—they are merely the best of a very poor lot. But in any event Cessna manuals provide most of the information a pilot needs to plan for emergencies. At this writing, a special committee of the General Aviation Manufacturer's Association is working on standardization and improvement of light aircraft flight manuals. But until such time as the GAMA committee and the FAA improve the situation, we're stuck with the paper work that comes with the airplane. Here comes rule five:

Rule #5—Be a skeptic when reading the performance tables in your Part 23 aircraft owners manual and be doubly sure you read the fine print. Add: plenty of fudge factors.

You'll notice first when you look at light-twin takeoff-performance tables (in anybody's manual) that the takeoff is initiated after power has been run to maximum with the brakes locked and the mixtures adjusted to optimum settings. We've attempted to measure the difference in the takeoff roll for brakes held versus a normal throttles-up-smooth start and have come up with figures ranging from an extra 200 to 400 feet. Remember that these figures will increase in density altitude.

If the book figures for continued single engine takeoff and accelerate/stop distances, you've really got it made, because now, by adding a few hundred feet here and there to compensate for real-time situations, you can

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get a good handle on what's going to happen if one quits—and what you're going to do about it.

We'll use a Cessna 421 for this exercise and remind you again that we're not picking on the 421. It's just that Cessna is honest enough to try to tell it like it is in its owners manuals.

On a standard day at 7,450 pounds, a 421 needs 2,500 feet to get off and over a 50-foot obstacle. This assumes a rotate speed of 106 knots, well above Vmc. If an engine is lost at rotation and the pilot elects to go anyway, he'll need a total of 5,000 feet to clear the obstacle. The ground run in both cases is about 2,000 feet. In the case of both engines operating, the climb from rotation to 50 feet requires a horizontal distance of only 500 feet; but in the case of the single-engine takeoff, the climb to 50 feet requires a horizontal distance of 3,000 feet, a six-fold increase. And keep in mind that we're still only 50 feet above ground and that to get this far we've made split-second decisions all along the way.

Let's get some real life factors into the single-engine takeoff equation. Suppose, as is usually the case, we begin the takeoff roll about 75 feet from the approach end of the runway and do so without holding the brakes. This could add 475 feet to the handbook figure. Next, suppose we lose the engine at rotation, but it takes us three seconds to recognize the situation and react. (This, by the way, is a very conservative figure.) The reaction time will cost us about 537 feet. Now the total horizontal distance from the beginning of the runway to a point at which the aircraft is 50 feet above the surface (assuming engine loss at rotation) is 6,012 feet, an increase of 20 percent. The 421's sea-level, single-engine climb rate is about 305 fpm. Assuming that we want to get at least 500 feet under us before trying anything fancy like returning for a landing, we must continue more or less straight ahead for one minute and 28 seconds. This climb will cover a horizontal distance of some 16,485 feet bringing the total distance covered from the rotation point to 19,485 feet, or 3.7 miles.

If all this happens at a sea-level airport on a hot day (ISA plus 20 degrees C.), we will not reach

the 50-foot level until the aircraft has covered a horizontal distance of 7,040 feet from the point of rotation and engine failure. Assuming calm air the aircraft will reach 500 feet some 5.9 miles from the rotation point or 6.6 miles from the runway beginning. If the hot condition brought convective turbulence with it, the effective climb rate would be reduced by 100 fpm. Under these conditions, the aircraft would reach 500 feet some 9.9 miles from the rotation point and 10.6 miles from the runway beginning.

I've been stating these horizontal distances in terms of miles to stress a point. If your flight manual gives figures for continued single engine takeoff, make sure you look at the climb performance beyond the 50-foot altitude to be certain that continued takeoff is a viable alternative if an engine quits. You might be able to live with that 10.6-mile hot-day figure on a departure from JFK where you could head out over the Atlantic, but the same departure from Teterboro would make collision with obstacles almost a certainty. In the case of the Teterboro departure, a rejected takeoff within the boundaries of the airport or stuffing it into the first available parking lot miles might be your only survivable alternative. You certainly aren't going to survive if you run into something, or fall out of the air trying to get performance from the aircraft that the manufacturer never built into it.

So, on the subject of rejected takeoffs, check the accelerate/stop tables and the landing distance charts before each takeoff. Remember to add 500 feet or so to the accelerate/stop distance to compensate for the runway left behind you when you moved into position and the rolling (rather than brakes-held) ground run; add another 500 feet or so for your reaction time and then another 200 feet for "technique." Part 23 sets no standards for the determination of accelerate/stop distances in light twins. The stopping distances are often determined by a 10,000-hour test pilot who does everything short of retracting the gear to stop the aircraft. Even in an emergency situation, you're probably not going to get the same stopping performance he does. (Remember to get the flaps up

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to increase the weight on the wheels.)

If you're lucky enough to have normal takeoff, single-engine takeoff and accelerate/stop tables in your airplane manual, another check you should make before takeoff is the total distance (adding our real-life factors, of course) for takeoff with both engines operating, climb to 50 feet, then to land from that 50-foot altitude and bring the aircraft to a complete stop. This figure for the 421 (adding all our fudge factors) comes to 5,689 feet. This is less than the distance required (6,012 feet) to climb to 50 feet assuming an engine loss at rotation under the same conditions.

Knowing this number gives you another alternative. If you have 5,700 feet of runway and overrun, you might decide to put the aircraft back on the runway even if the engine failure occurs well after takeoff as you're going through 50 feet. Even if you don't have the full 5,700 feet, you may have enough runway to get the wheels back on the hard surface and begin some serious braking before you run off the end of the runway. B/CA's philosophy, which was copied from that of the flight department of a major manufacturer of light twins, is that it's always better to go through the fence at 50 knots than to hit the trees at 120.

To the best of my knowledge, a takeoff to 50 feet followed by an immediate landing is not taught in twins, although a similar maneuver is taught in single-engine aircraft. It should be, but before you go out and try it, take your aircraft to altitude and practice the transition from climbing flight to gliding flight until you can make the transition without significant loss of airspeed. And it might be a good idea to take an instructor along. If you decide to try it on a runway allow a good 8,000 to 10,000 feet for the first few attempts—and take your time.

If your aircraft-owners manual does not show performance figures for continued single engine takeoff, chances are that the airplane simply is not capable of accelerating from liftoff speed to a reasonable climb speed in the takeoff configuration. In this case, your decisions are pretty limited. You really don't have a go-situation until the aircraft is cleaned up and has

reached at least best single-engine angle-of-climb speed. An engine failure before that time (on the ground or in the air) dictates an immediate controlled descent to a landing. The surviving engine, in this case, can be used to help maneuver to a suitable (nearby) landing place if all of the runway is gone.

You can calculate your own accelerate/stop distances by running the aircraft up to takeoff speed and then bringing it to a stop. (Make sure you start these tests on a good long runway). Do this several times at max gross weight counting runway lights (the airport operator can tell you the distance between lights) and you'll get a good ball-park figure for accelerate/stop. Then use that figure in your future takeoff planning.

To sum it up, we've seen that:

- The loss of an engine on a Part 23 twin will decrease sea-level climb performance by at least 80 percent and can decrease it by as much as 90 percent.
- There is no requirement for continued single-engine takeoff capability for Part 23 twins, nor, in fact, is there a requirement for any positive single-engine climb at all for twins which weigh less than 6,000 pounds and have a stall speed of 61 knots or less in the landing configuration.
- It is vital to know all you can about your aircraft's performance in normal and emergency situations before the takeoff is attempted. To arrive at reasonable performance predictions you must adjust the information, provided by the manufacturer to take into account real-life factors such as reaction time, runway condition and obstacles, including obstacles five or more miles beyond the airport boundary.
- A well-executed Part 23-twin takeoff is one in which the aircraft leaves the ground at least at  $V_{mc} + 5$  knots and climbs at a speed of at least  $V_{xse}$  and not more than  $V_y$ .

# Oral Exam Guide

## V<sub>mc</sub>

A thorough knowledge of V<sub>mc</sub> is probably the most important subject on the oral exam.

- Be able to define V<sub>mc</sub>
- How does the manufacturer determine V<sub>mc</sub> speed?
- What happens to V<sub>mc</sub> speed if the aircraft is loaded aft of the C.G. limit?

## How V<sub>mc</sub> is Determined

### COMBATS

Critical engine failed / windmilling

Operating engine T/O power

Max gross weight

Bank 3° to 5° into good engine

Aft CG

Takeoff configuration

Standard day 29.92 15°C

Good (Lowers V<sub>mc</sub>)  
Add power to critical  
Reduce drag  
Reduce power  
CG forward  
Gear down  
Lower pressure  
Higher altitude  
Higher temperature

Bad (Increases V<sub>mc</sub>)  
Reduce bank  
Higher pressure  
Lower temperature  
Lower altitude

## Critical Engine

- Be able to define "critical engine"
- Why does it apply to some multiengine aircraft and not others?
- Does it apply to the BE-76?

## Performance Charts

- Takeoff distance
- Accelerate-stop distance
- Accelerate-Go distance
- Climb performance: 2 engine, 1 engine
- Cruise chart: TAS, fuel flow, range
- Single engine service ceiling
- Landing distance: flaps down/flaps up

## Weight and Balance

- Be able to use charts and graphs in BE-76 manual
- Explain zero fuel weight

# Oral Exam Guide

## Aircraft Systems

### Fuel system:

- 1) number of fuel tanks
- 2) capacity (total / usable)
- 3) fuel drains
- 4) fuel pumps
- 5) crossfeed procedure

### Electrical system:

- 1) battery volts/amps
- 2) alternator volts/amps

### Landing gear:

- 1) describe system operation
- 2) safety retraction
- 3) gear warning systems
- 4) manual extension procedure

### Pressure system:

- 1) number of pumps
- 2) what do they operate

### Heater System:

Location  
BTU  
How does it work  
Automatic safety switch ( if exceeds 300°F)  
Fuel burn per hour  
Which tank

## Operating Airspeeds

Vy	Vmc	Vlo	Vso
Vyse	Va	Vle	Vsl
Vx	Vlof	Vfe	Vsse
Vxse			

## Miscellaneous

### Duty Starter Limits

1. 30 seconds crank, 2 minutes rest
2. 30 seconds crank, 2 minutes rest
3. 30 seconds crank, 30 minutes rest

### Max Side Slip

30 seconds

### Oxygen Requirements

### Spin Recovery