Multi-Engine Airplane Guide

PA-44-180 Piper Seminole

Written by Robert Thomas
Cover picture courtesy of Steven Pellegrino.

TABLE OF CONTENTS

INTRODUCTION TO MULTI-ENGINE AIRCRAFT

The ERAU Multi-Engine Aircraft Guide provides supplemental information to assist you in learning the many factors when dealing with flying a multi-engine ("light twin") airplane.

The term "light-twin," although not formally defined in the Federal Aviation Regulations, is defined as a small multi-engine airplane with a maximum certificated takeoff weight of 6,000 pounds or less.

The basic differences between operating multi-engine airplanes and single-engine airplanes are that multi-engine airplanes are:

- Generally capable of flying at faster airspeeds and higher altitudes,
- Typically larger in size and have more complex systems, and
- More demanding and that pilots have additional knowledge and understanding of the conditions associated with operating with one engine inoperative.

While there are a few differences between taxiing single-engine and multi-engine airplanes, the most noticeable difference is typically the increase in wingspan. With an increase in wingspan, there is an even greater need for vigilance when taxiing in close quarters. In addition, the multi-engine airplane may not be as nimble or responsive to steering inputs as the smaller single-engine airplane.

One advantage of a multi-engine airplane over a single-engine airplane is the differential power capability. Turning the airplane during taxi with the assistance from differential power minimizes the need for brakes during turns and while maintaining the same turning radius. Differential power, however, does NOT need to be used during every turn, or as the primary way to turn the airplane. It is also important to remember to keep engine power to a minimum and not "ride" the brakes.

Unless otherwise directed by the AFM/POH, all ground operations should be conducted with the cowl flaps fully open to ensure adequate engine cooling.

When operating a multi-engine airplane with one engine inoperative, the penalties for loss of an engine are twofold: performance and control. The most obvious problem related to airplane performance is the loss of power (50%). This loss reduces climb performance by 80 – 90%, sometimes even more. The second problem affects aircraft control caused by the remaining thrust, which is now asymmetrical. Attention to both of these factors is crucial in maintaining safe, one-engine inoperative flight.

For pilots, flying a multi-engine airplane is an exhilarating yet challenging experience. To take full advantage of the airplanes capabilities, performance, and safety, the pilot must be well-trained, knowledgeable, and proficient.

V-SPEEDS

Multi-Engine airplanes use the same “V”-speeds as single-engine airplanes. However, multi-engine airplanes have additional V-speeds and airspeed indicator markings relating to one engine inoperative flight.

Unless otherwise noted, V-speeds given in the AFM/POH/IM apply to sea level pressure, and standard day conditions at the airplane’s maximum certificated takeoff weight. Performance speeds will vary with aircraft weight, configuration, and atmospheric conditions.

V_R – Rotation speed. The speed at which back-pressure is applied to rotate the airplane to a takeoff attitude.

V_{LOF} – Lift-off speed. The speed at which the airplane leaves the surface. Some manufacturers reference takeoff performance data to V_R, others to V_{LOF}.

V_X – Best angle of climb speed. The speed at which the airplane will gain the greatest altitude for a given distance of forward travel.

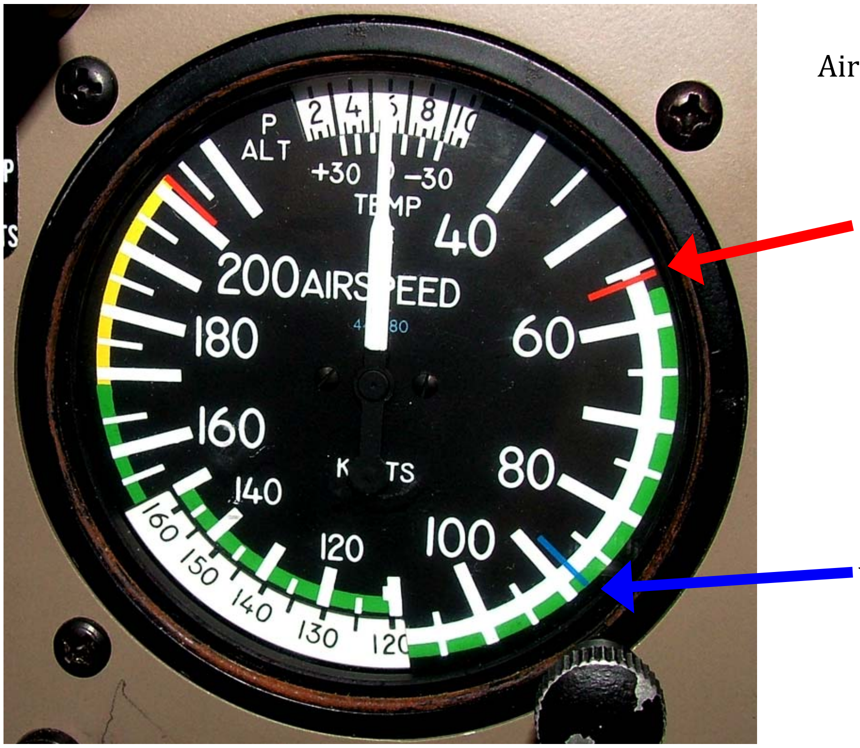
V_{XSE} – Best angle-of-climb speed with one engine inoperative.

V_Y – Best rate of climb speed. The speed at which the airplane will gain the most altitude for a given unit of time.

V_{YSE} – Best rate-of-climb speed with one engine inoperative.
- Marked with a blue radial line on most airspeed indicators.

V_{SSE} – Safe, intentional one-engine-inoperative speed. Originally known as safe single-engine speed, it is the minimum speed to intentionally render the critical engine inoperative.
- Required by 14 CFR Part 23, Airworthiness Standards, to be established and published in the AFM/POH.

V_{MC} – Minimum control speed with the critical engine inoperative. The minimum speed at which directional control can be maintained under a very specific set of circumstances outlined in 14 CFR Part 23, Airworthiness Standards.
- Marked with a red radial line on most airspeed indicators.
- V_{MC} only addresses directional control. There is no requirement that the airplane be capable of climbing at this airspeed.



Airspeed indicator markings from a Piper Seminole

V_{MC} – Red Radial Line

V_{YSE} – Blue Radial Line

If an engine failure occurs below V_{MC} while the airplane is on the ground, the takeoff must be rejected. Directional control can only be maintained by promptly closing both throttles and using rudder and brakes as required.

If an engine fails below V_{MC} while airborne, directional control is not possible with the remaining engine producing takeoff power. So for safety reasons, the airplane should never be airborne during takeoff before the airspeed reaches AND exceeds V_{MC}.

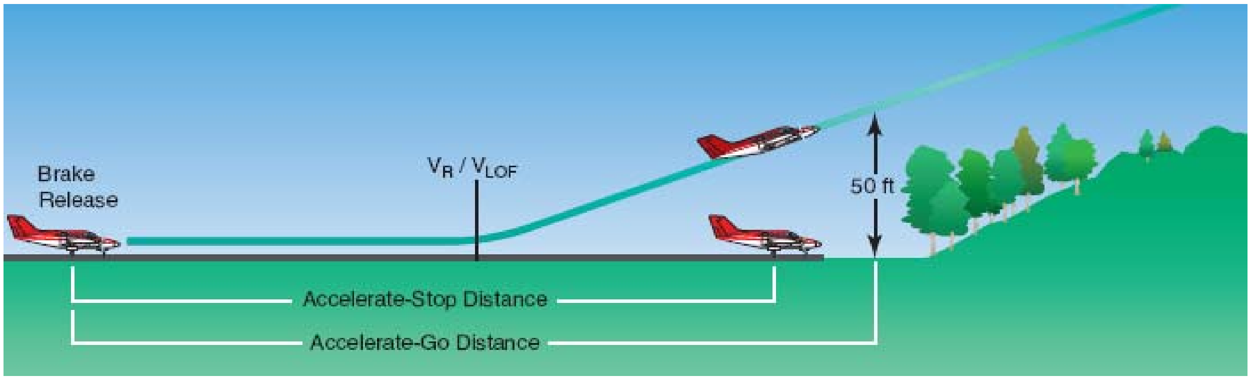
After liftoff, gain altitude as rapidly as possible. Once leaving the ground, **altitude gain is more important than achieving excess of airspeed**. Altitude also gives the pilot time to think and react if an engine failure occurs. V_Y should be established and maintained until reaching a safe single-engine maneuvering altitude. Considering terrain and obstructions, this is typically achieved at a minimum of 400-500' AGL.

There will be more information on all the factors involved in single engine operation of the airplane and the factors affecting V_{MC} speed later in this guide.

PERFORMANCE AND LIMITATIONS

Accelerate-stop distance is the runway length required to accelerate to a specified speed (either V_R or V_{LOF}, as specified by the manufacturer), experience an engine failure, and bring the airplane to a complete stop.

Accelerate-go distance is the horizontal distance required to continue the takeoff and climb to 50' AGL., assuming an engine failure occurs at V_R or V_{LOF}, as specified by the manufacturer (see diagram below).



The FARs do not specifically require that the runway length be equal to or greater than the accelerate-stop distance. Most AFM/POH publish accelerate-stop distances only as an advisory. It becomes a limitation only when published in the limitations section of the AFM/POH. Using runway lengths of at least the accelerate-stop distance is a good operating and safety practice.

ENGINE CEILINGS

All-Engine Service Ceiling - the highest altitude at which the airplane can maintain a steady rate of climb of 100 fpm with both engines operating at full power.

All-Engine Absolute Ceiling - the altitude where climb is no longer possible with both engines operating at full power.

Single-Engine Service Ceiling - the highest altitude at which the airplane can maintain a steady rate of climb of 50 fpm with one engine operating at full power and one engine's propeller feathered.

Single-Engine Absolute Ceiling - the altitude where climb is no longer possible with one engine operating at full power and one engine's propeller feathered.

If the airplane is flying above the single-engine service ceiling and one engine fails in flight, the airplane will drift down from its current altitude to the single-engine service ceiling.

- Above the single-engine absolute ceiling, V_{YSE} yields the minimum rate of sink.
- For example if an airplane's single-engine absolute ceiling is 5,000 ft. and while cruising at 9,000 ft. an engine fails, the airplane will drift down (descend) to 5,000 ft.

SINGLE-ENGINE CLIMB PERFORMANCE

FAR 23.67 provides the single-engine climb performance requirements to airplane manufacturers for FAA certification of multi-engine aircraft.

For aircraft with a maximum weight of 6,000 lbs., or less and a V_{S0} of 61 knots or less:
The single-engine rate of climb at 5,000' MSL must simply be determined with the—

1. Critical engine inoperative and its propeller in the minimum drag position
2. Remaining engine(s) at no more than maximum continuous power
3. Landing gear retracted
4. Wing flaps retracted
5. Climb speed not less than $1.2V_{S1}$

- The rate of climb could be a negative number – meaning a descent
- There is no requirement for a single-engine positive rate of climb at 5,000 ft., or any other altitude.

For Aircraft with a maximum weight of 6,000 lbs. or less, and/or V_{S0} more than 61 knots:
If certified *before* February 4, 1991: the single engine rate of climb in feet per minute at 5,000' MSL must be equal to at least $.027\ V_{S0}^2$ (V_{S0} Squared)

If certified *after* February 4, 1991: maintain a steady climb gradient of at least 1.5 percent at a pressure altitude of 5,000 ft. with the—

1. Critical engine inoperative and its propeller in the minimum drag position
2. Remaining engine(s) at no more than maximum continuous power
3. Landing gear retracted
4. Wing flaps retracted
5. Climb speed not less than $1.2\ V_{S1}$

NOTE

Do not confuse the date of type certification with the airplane's model year.

Rate of climb is the altitude gain per unit of time.
Climb gradient is the actual measure of altitude gained per 100 ft. of horizontal travel, expressed as a percentage.

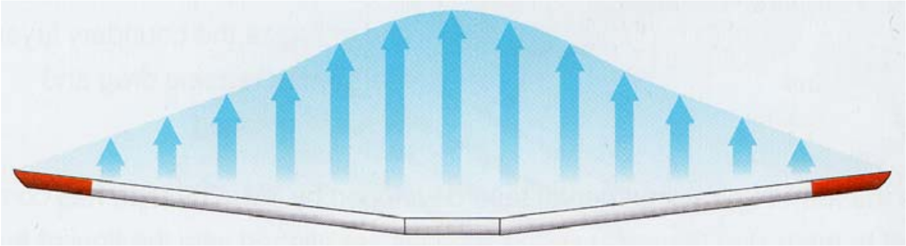
- An altitude gain of 1.5 ft. per 100 ft. of horizontal travel (or 15 ft. per 1,000, or 150 ft. per 10,000) is a climb gradient of 1.5 percent.

Climb gradient may also be expressed as a function of altitude gain per nautical mile, or as a ratio of the horizontal distance to the vertical distance (e.g., 50:1). Unlike rate of climb, the climb gradient is affected by wind. A climb gradient is improved with a headwind component and reduced with a tailwind component.

MULTI-ENGINE AERODYNAMICS

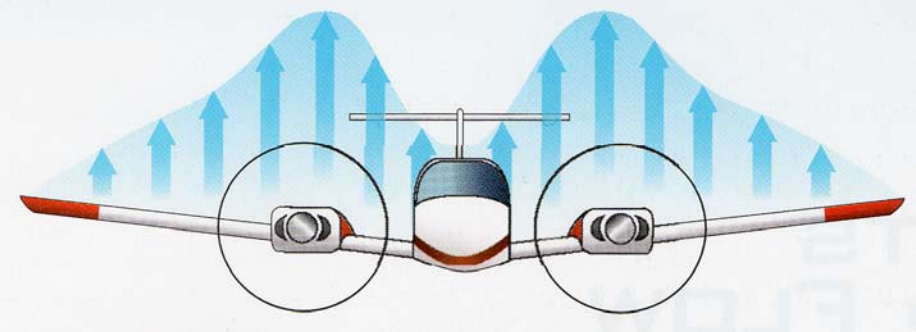
INDUCED FLOW

Looking at the airplane without the engines and the fuselage, the amount of lift created by the wings would look like this:



Jeppesen Multi-Engine Manual

The propellers of the wing mounted engines create an accelerated flow or accelerated slipstream of air over the wings called induced flow. The amount of lift created by a multi engine airplane looks like this:



Jeppesen Multi-Engine Manual

Induced flow does occur in single-engine airplanes, but it is not as much of a factor because of the location of the engine in relation to the wings.

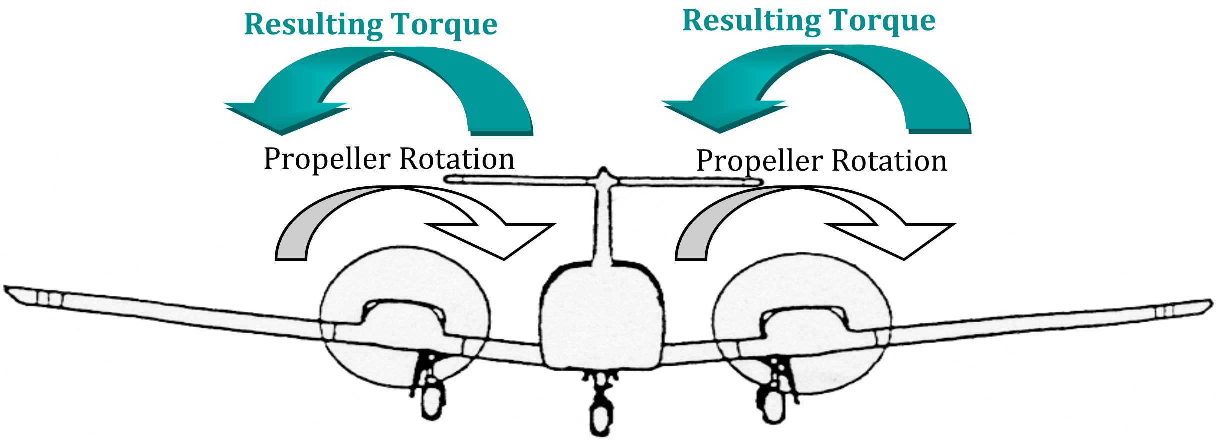
TURNING TENDENCIES

The turning tendencies that affect single engine airplanes (i.e. torque and P-factor) also affect multi-engine airplanes. Since the multi-engine airplane has at least two engines, these effects are increased.

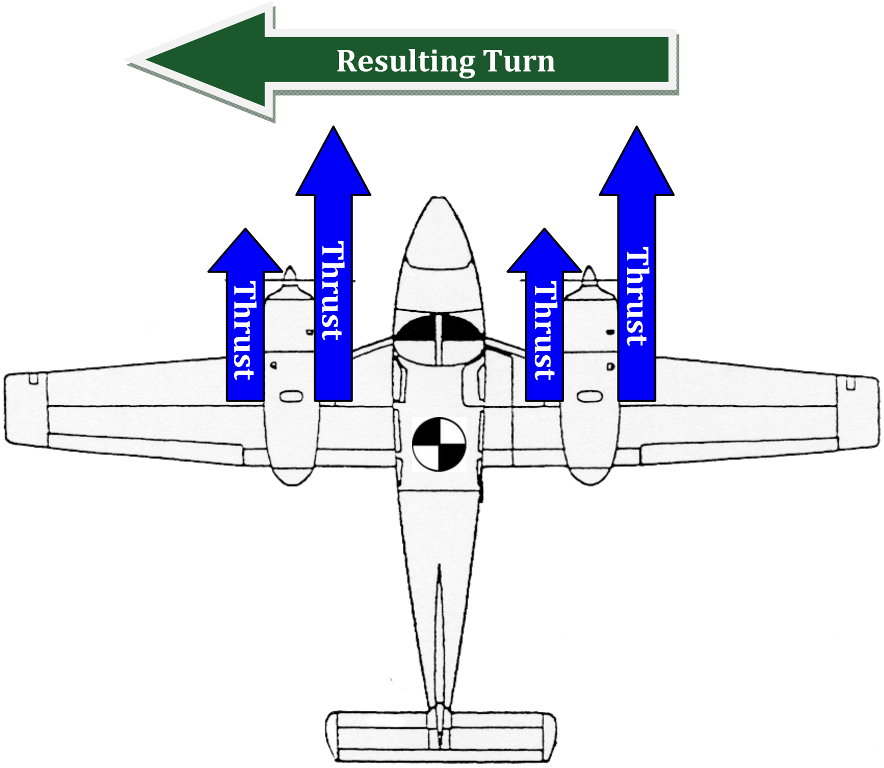
Twin-engine airplanes where the propellers for each engine rotate in the same direction are called **conventional** twins. To combat the torque and P-factor tendencies, twin-engine airplanes with **counter-rotating** propellers, or propellers that rotate in opposite directions, and engines have been developed. The effects of torque and p-factor with counter-rotating propellers will cancel each other out, resulting in less rudder needed to oppose these forces.

A Conventional Twin

Result of Torque = Roll to the Left

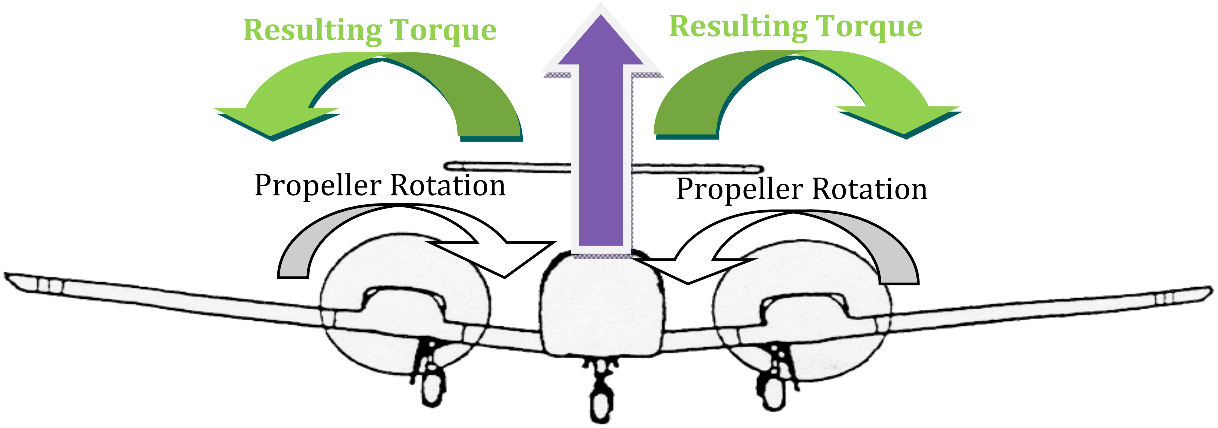


Result of P-Factor = Yaw to the left

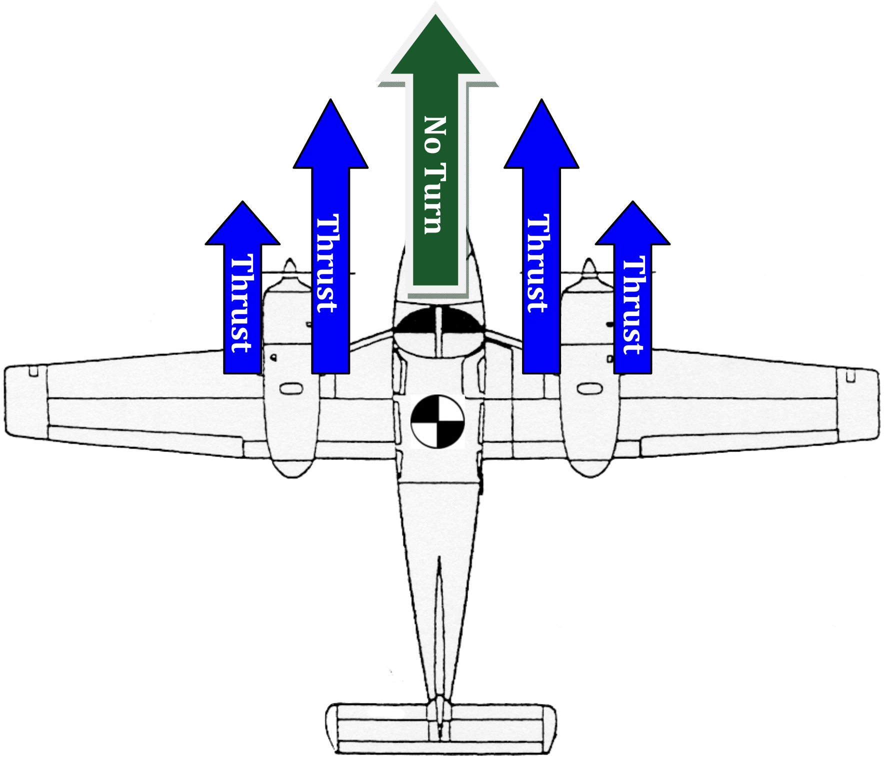


A Counter-Rotating Twin

Result of Torque = NONE = Both Engines Cancel Each Other Out.



Result of P-Factor = NONE = Both Engines Cancel Each Other Out.

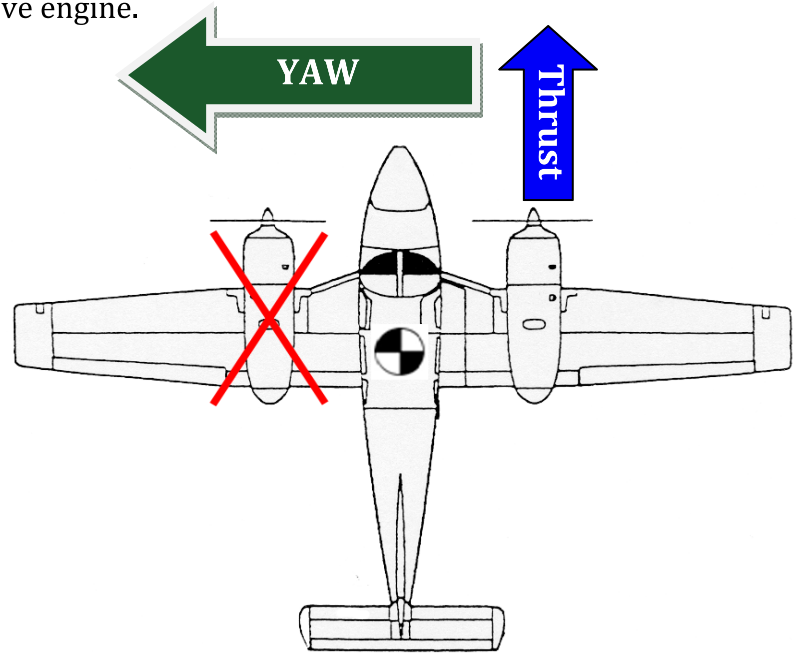


ENGINE FAILURES

WHAT HAPPENS WHEN AN ENGINE FAILS

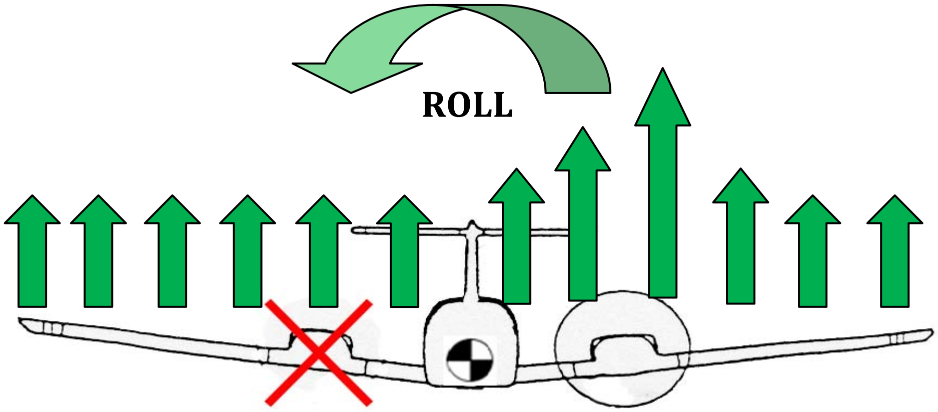
Two motions happen when an engine fails: YAW and ROLL.

1. **YAW**- Asymmetrical thrust will cause a yawing moment around the C.G. towards the inoperative engine.



2. **ROLL** – The yawing moment from above will cause the wing with the operating engine to move faster through the air as the airplane yaws. This causes a faster velocity of air over the wing with the operative engine meaning more lift on that wing and results in a roll towards the inoperative engine.

3. **ROLL** – Induced flow (accelerated slipstream) over the wing from the operating engine and lack of induced flow (accelerated slipstream) over the inoperative engine causes asymmetrical lift on the wings, resulting in a rolling moment around the C.G. towards the inoperative engine.



CRITICAL ENGINE

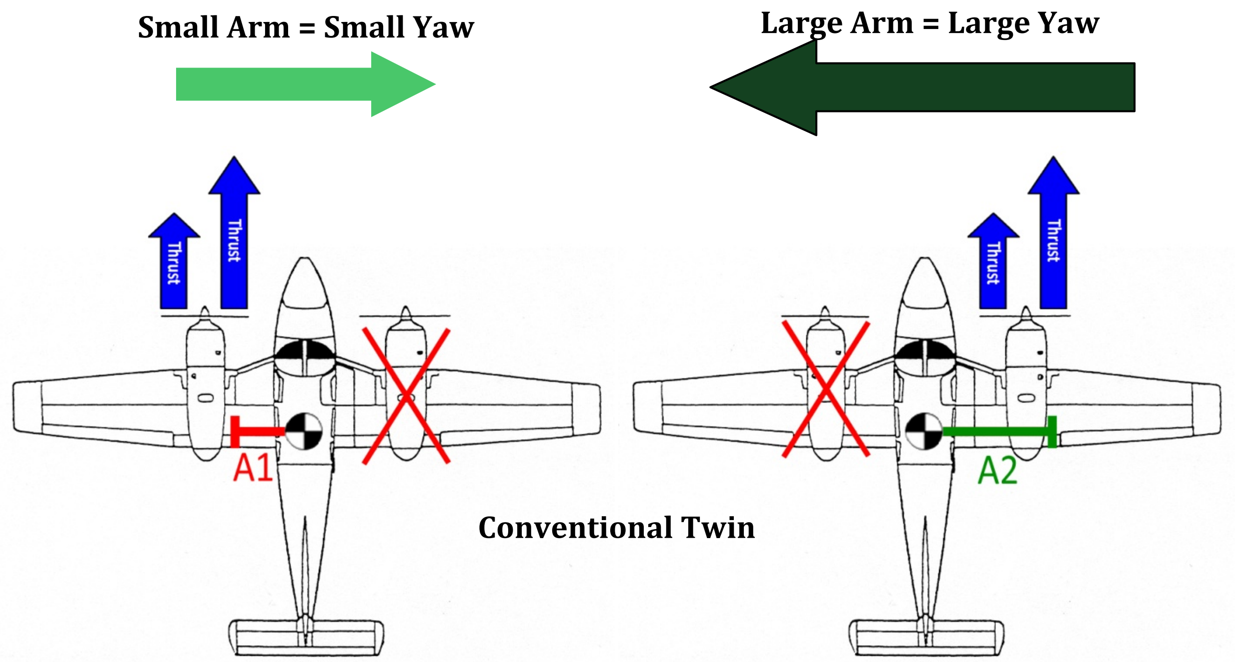
The critical engine is the engine that, if it were to fail, would most adversely affect the performance or handling characteristics of the airplane.

On **conventional twins** (with propellers rotating to the right) the critical engine is the **left engine**. On a twin engine airplane with **counter-rotating** propellers there is **not a critical engine** since the yawing and rolling effects of losing one engine will be identical no matter which engine fails.

There are three factors that determine is an engine is critical.

1. P-Factor
2. Accelerated Slipstream
3. Torque

P-FACTOR - P-factor is where the descending propeller blade creates more thrust than the ascending blade. This causes asymmetrical thrust on each side of the propeller. To figure out the effect on the airplane, the formula **THRUST x Arm = Moment** can be used. This means that the longer the arm from the C.G. to the thrust, the larger the yawing moment will be.


Small Arm = Small Yaw

Large Arm = Large Yaw

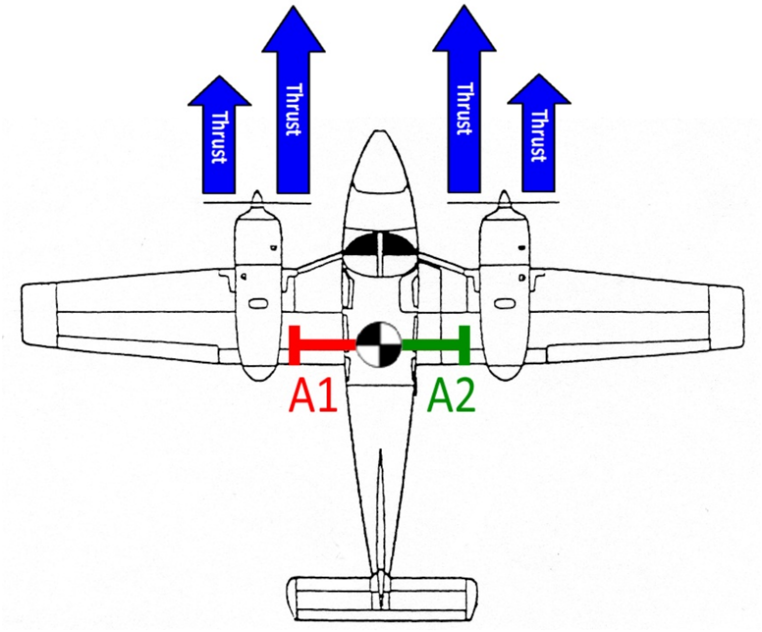
Conventional Twin

Because the descending propeller blade on the right wing engine has a longer arm (A2) than the descending propeller blade on the left wing engine (A1), the airplane will have a greater yawing moment to the left if the left engine fails than if the right engine fails.

Since the effect of the yaw is greater if the left engine fails, **the left engine is the critical engine**.

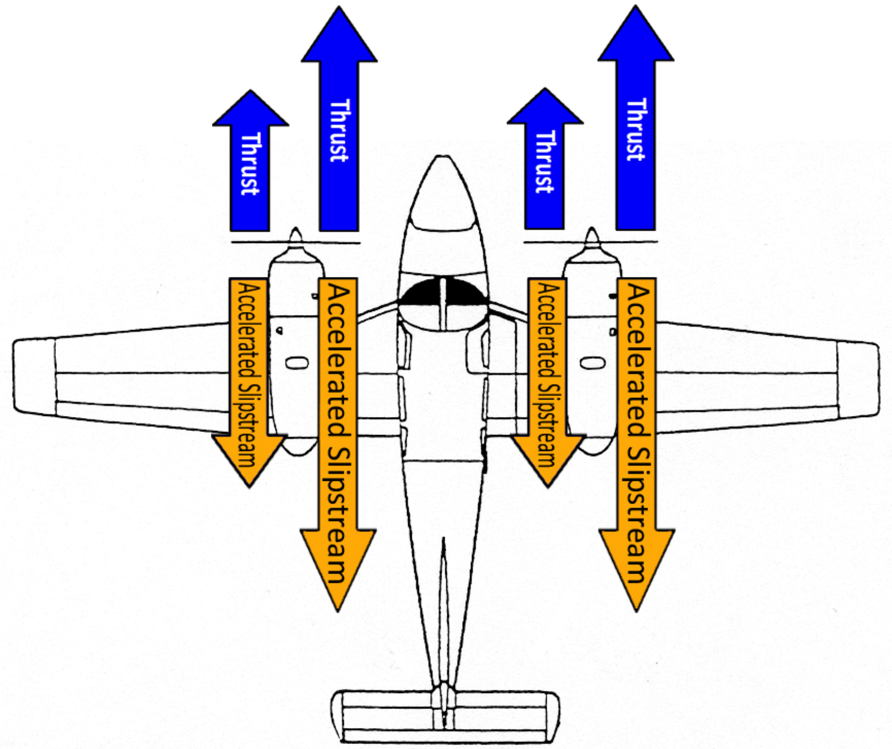
On a counter-rotating twin-engine airplane, arms (A1, A2) to the descending propeller blades are the same length, resulting in the same amount of yaw regardless of which engine fails.

Counter-rotating Twin = Arms are the Same Length



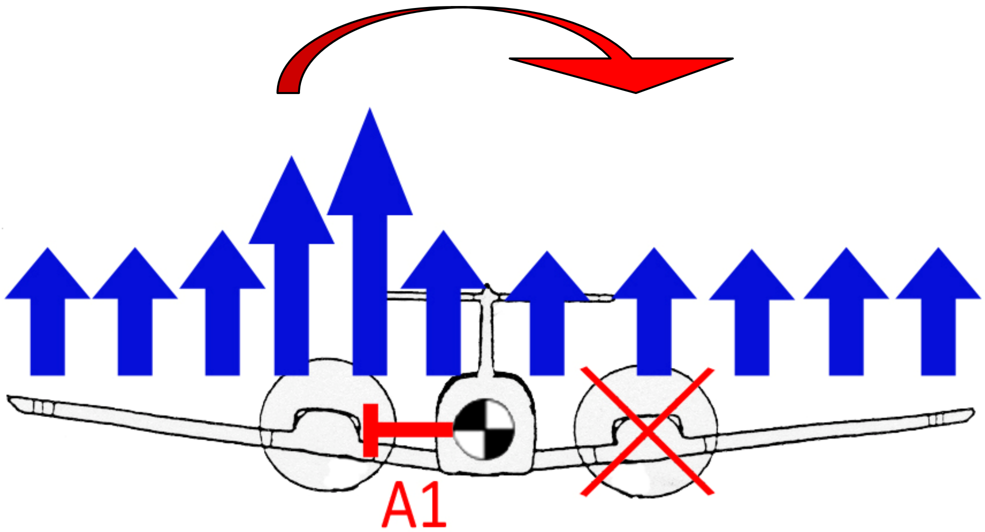
ACCELERATED SLIPSTREAM – The propellers will accelerate air over the wings. More lift is produced where the propellers accelerate the air over the wing. Just as P-factor causes asymmetrical thrust forward, it also produces the same effect in the asymmetrical airflow behind the propeller.

Conventional Twin

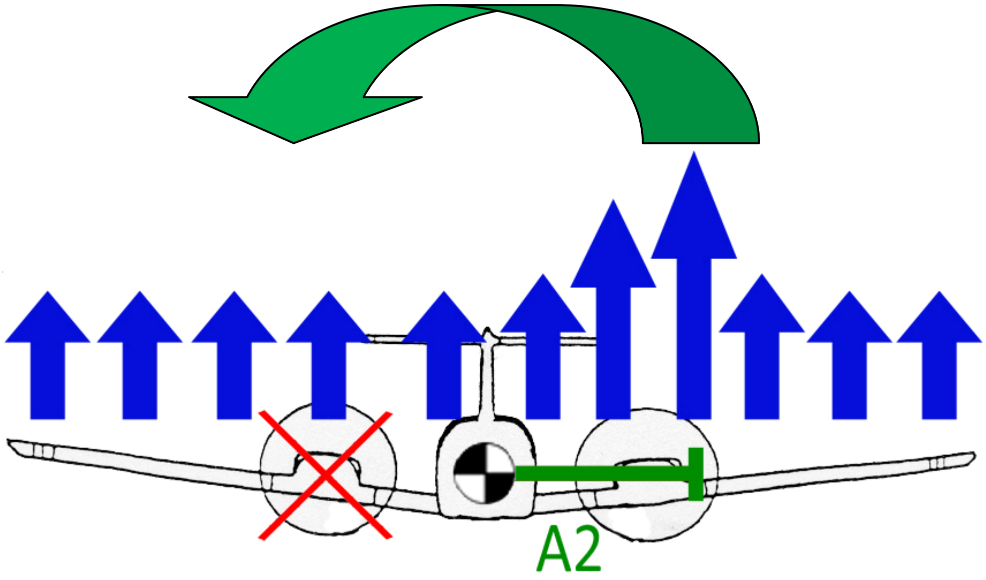


When one engine fails, the accelerated slipstream causes a roll towards the inoperative engine. To figure out the effect on the airplane the formula **LIFT x Arm = Moment** can be used. Just like P-factor, the arm to the right engine is longer than the arm to the left engine. This means that if the left engine fails, the roll moment will be greater to the left than if the right engine fails. **Therefore the left engine is the critical engine**.

Small Arm = Small Roll

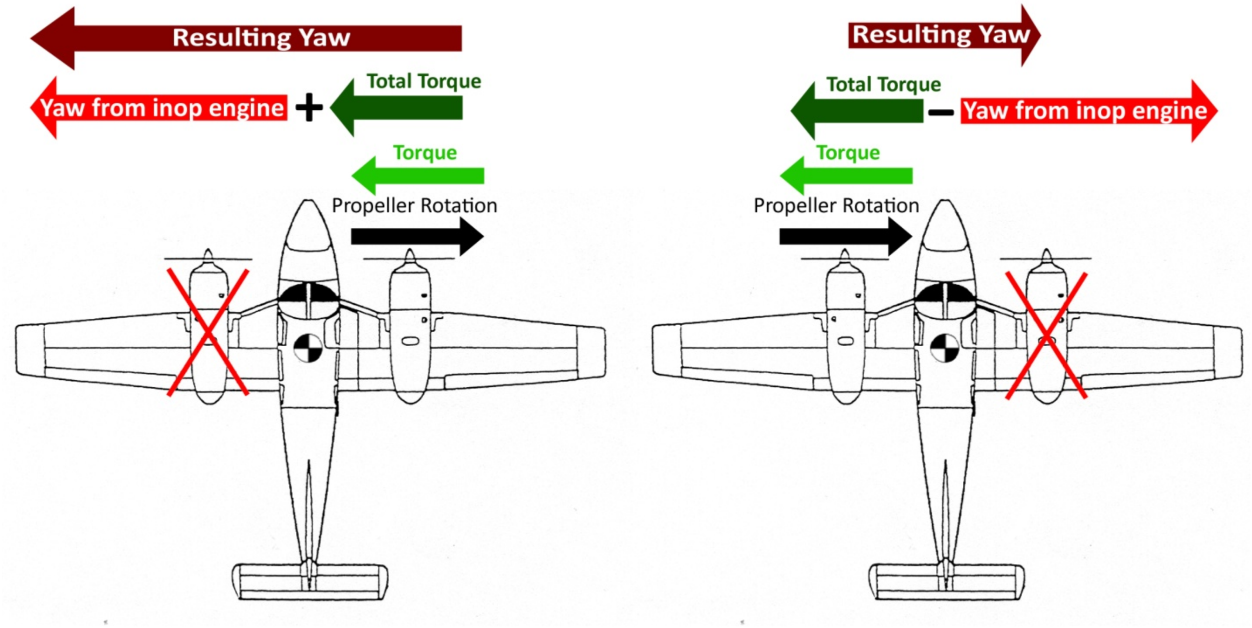


Large Arm = Large Roll



TORQUE – As the engine and propeller rotate in one direction, they, in turn, try to rotate the airplane in the other direction. This is due to Newton's third law which states, "For every action there is an equal and opposite reaction." This force also acts when an engine fails because there is still a second operating engine.

Conventional Twin



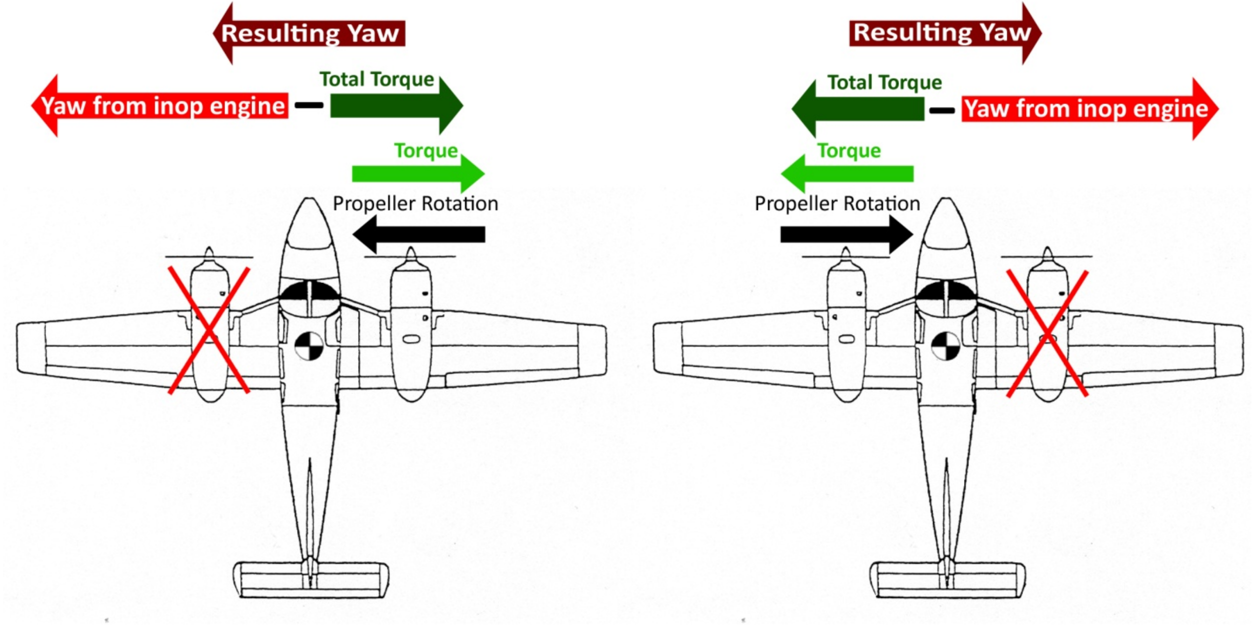
The result of the torque is roll, but it will also combine with the other factors previously mentioned as well.

If the left engine fails, the yawing moment from the right engine (thrust) and the total torque will both work together to yaw and roll the airplane to the left.

If the right engine fails, the yawing moment from the left engine (thrust) and the total torque (opposite direction) will still result, although to a lesser degree (compared to failure of the left engine), in a yaw and roll of the airplane to the right.

This means that the yaw will be worse if the left engine fails which means that the **left engine is the critical engine**.

Counter-Rotating Twin

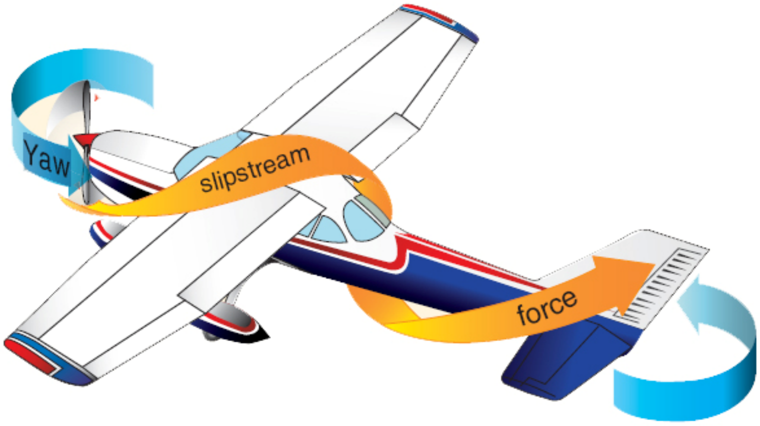


In the counter-rotating twin, the torque will oppose the yawing and rolling moment caused by an inoperative engine. The resulting yaw will be the same no matter which engine fails. Therefore, there is no critical engine.

One other factor that could affect the critical engine is **Spiraling Slipstream**.

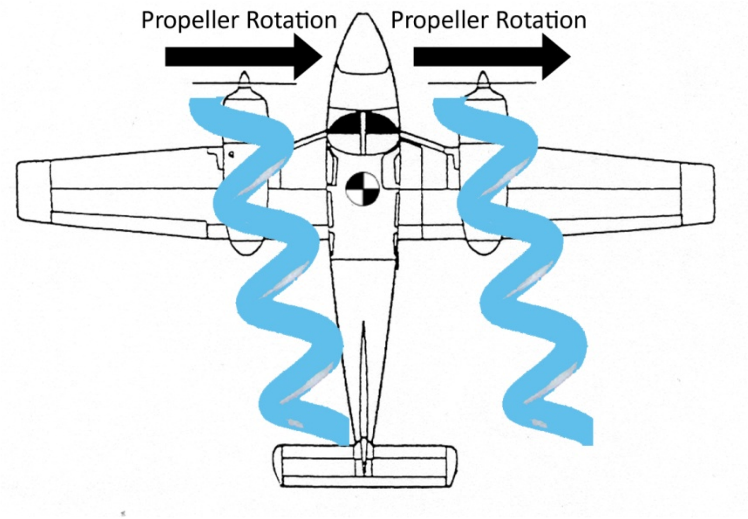
NOTE
The effect of Spiraling Slipstream is usually so minimal that some will even ignore its effects altogether.

The high-speed rotation of an airplane propeller gives a corkscrew or spiraling rotation to the slipstream. At high propeller speeds and low forward speed (as in takeoffs and approaches to power on stalls), this spiraling rotation is very compact and exerts a strong sideward force on the airplane's vertical tail surface.

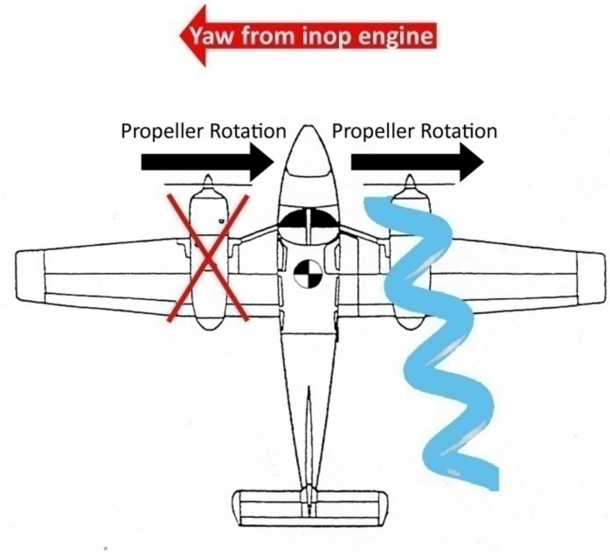


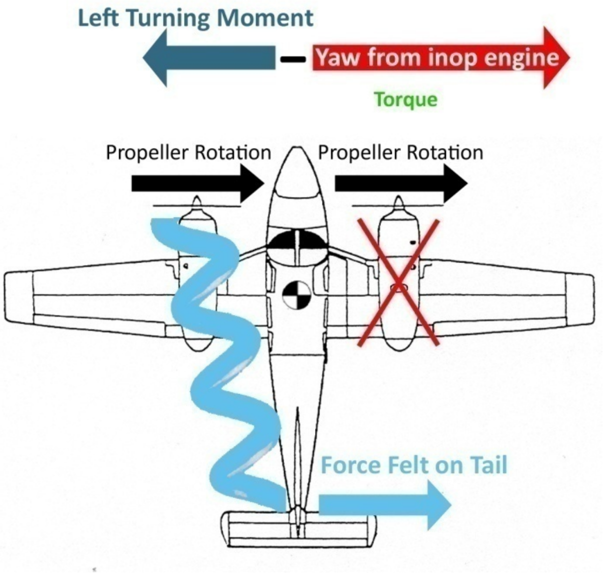
When this spiraling slipstream strikes the vertical fin on the left, it causes a left turning moment, or yaw, about the airplane's vertical axis. The more compact the spiral, the more prominent the force. As the forward speed increases, however, the spiral elongates and becomes less of a force on the vertical fin.

Here is what spiral slipstream would look like on a conventional twin with both engines operating. As the propeller turns right, the air is also moved to the right.



If the left engine fails the spiral slipstream will not hit the tail at all, resulting in no additional yawing force. If the right engine fails the spiral slipstream will hit the left side of the tail causing a yaw to the left in the opposite direction of the yaw to the right caused by the failed engine. This yaw from the spiral slipstream will help oppose the yaw from the failed engine. This makes the left engine critical.

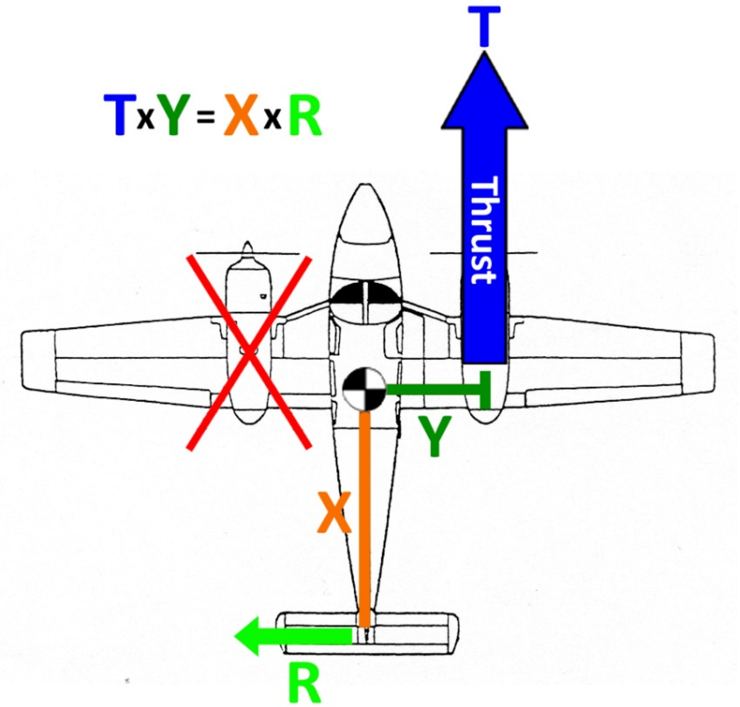




V_{MC}

When a multi-engine airplane loses an engine it experiences a yaw and roll. To counteract this, the rudder can be used to stop the yaw and the resulting roll.

As airspeed is decreased, the rudder becomes less effective. Therefore, more rudder deflection will be required to maintain directional control. Eventually, an airspeed will be reached where full rudder deflection will be required to maintain directional control. At this point, any further decrease in airspeed will lead to loss of directional control. It is this airspeed at which the airplane reaches V_{MC}.



V_{MC} can be defined as:

1. Minimum control speed with the critical engine inoperative.
2. The minimum speed at which directional control can be maintained under a very specific set of circumstances as outlined in 14 CFR Part 23.

V_{MC} is the speed at which it is still possible to maintain directional control with an engine inoperative.

NOTE
V_{MC} only addresses directional control.

V_{MC} FOR CERTIFICATION – FAR 23.149

Every multi-engine airplane must go through a certification process which includes calculating a V_{MC} speed. V_{MC} is NOT a fixed airspeed under all conditions. V_{MC} is a fixed airspeed only for the very specific set of circumstances under which it was determined during aircraft certification by FAR 23.149.

§23.149 Minimum control speed

V_{MC} is the calibrated airspeed at which, when the critical engine is suddenly made inoperative it is possible to:

1. Maintain control of the airplane with that engine still inoperative,
2. Maintain straight flight at the same speed with an angle of bank of not more than 5 degrees.

The method used to simulate critical engine failure must represent the most critical mode of powerplant failure expected in service with respect to controllability.

V_{MC} must not exceed 1.2 V_{S1} at maximum takeoff weight.

V_{MC} must be determined with:

1. Most unfavorable weight - (not necessarily maximum gross weight)
2. Most unfavorable center of gravity position
3. The airplane airborne and the ground effect negligible
4. Maximum available takeoff power initially on each engine
5. The airplane trimmed for takeoff
6. Flaps in the takeoff position
7. Landing gear retracted
8. All propeller controls in the recommended takeoff position.

When recovering from V_{MC}:

1. The rudder pedal force required to maintain control must not exceed 150 pounds.
2. It must not be necessary to reduce power of the operative engine(s).
3. The airplane must not assume any dangerous attitude.
4. It must be possible to prevent a heading change of more than 20 degrees.

NOTE
V_{MC} deals only with directional control not performance.

FAR 23.149 also requires the calculation of a minimum speed to intentionally render the critical engine inoperative and to be designated as the safe, intentional, one-engine-inoperative speed, or V_{SSE}.

Remember, published V_{MC} and actual V_{MC} are two different speeds. There are many factors that can affect V_{MC} speed and they will be covered in the following pages.

RECOGNIZING AND RECOVERING FROM V_{MC}

To recognize V_{MC} is occurring or about to occur there are four warning signs.

1. **Loss of directional control** – the rudder pedal is depressed to its fullest travel and the airplane is still turning towards the inoperative engine.
2. **Stall warning horn** – a single-engine stall could be just as dangerous as running out of rudder authority and could even result in a spin.
3. **Buffeting before the stall** – same reason as the stall warning horn.
4. **A rapid decay of control effectiveness** – any loss of control effectiveness could result in loss if control of the airplane.

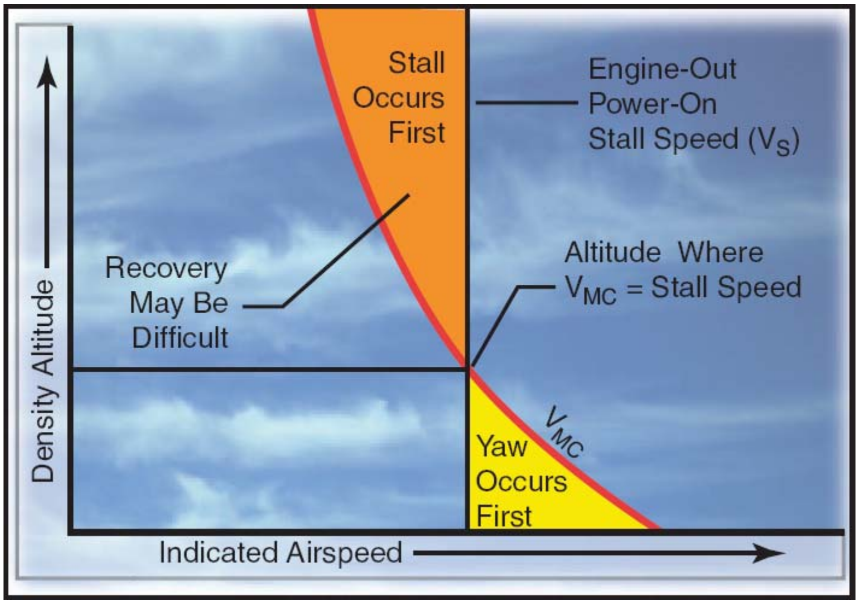
To recover from $V_{MC,}$ two actions must occur (simultaneously):

1. **Reduce power on the operating engine** – this will reduce the asymmetrical thrust causing the V_{MC} in the first place.
   - Reducing the power all the way to idle may help stop the $V_{MC,}$ but the loss of power and resulting loss of airspeed could lead to a stall.
2. **Pitch down** – Lowering the nose of the airplane will increase the forward airspeed making the rudder more effective in regaining and maintaining directional control.

V_{MC} vs. STALL SPEED

As density altitude increases, V_{MC} speed decreases due to the fact that as density altitude increases engine power will decrease. The decrease in engine power results in less asymmetrical thrust, meaning the yawing from a failed engine will be less at a high density altitude than a lower density altitude.

Stall speed is an indicated airspeed and will remain constant as altitude increases or decreases.



FACTORS AFFECTING V_{MC}

Published V_{MC} will almost always be different than actual V_{MC}. There are a lot of factors that can affect this speed, but there are a few important things to remember:

V_{MC} becoming a lower airspeed is good because the airplane can go slower before losing directional control.
Things that causes V_{MC} to decrease:

- Anything that will move the C.G. forward will make the rudder more effective.
    - Large arm to rudder = Larger rudder moment = Rudder more effective.
- Anything that will allow less rudder to be used, making more rudder available to the pilot.

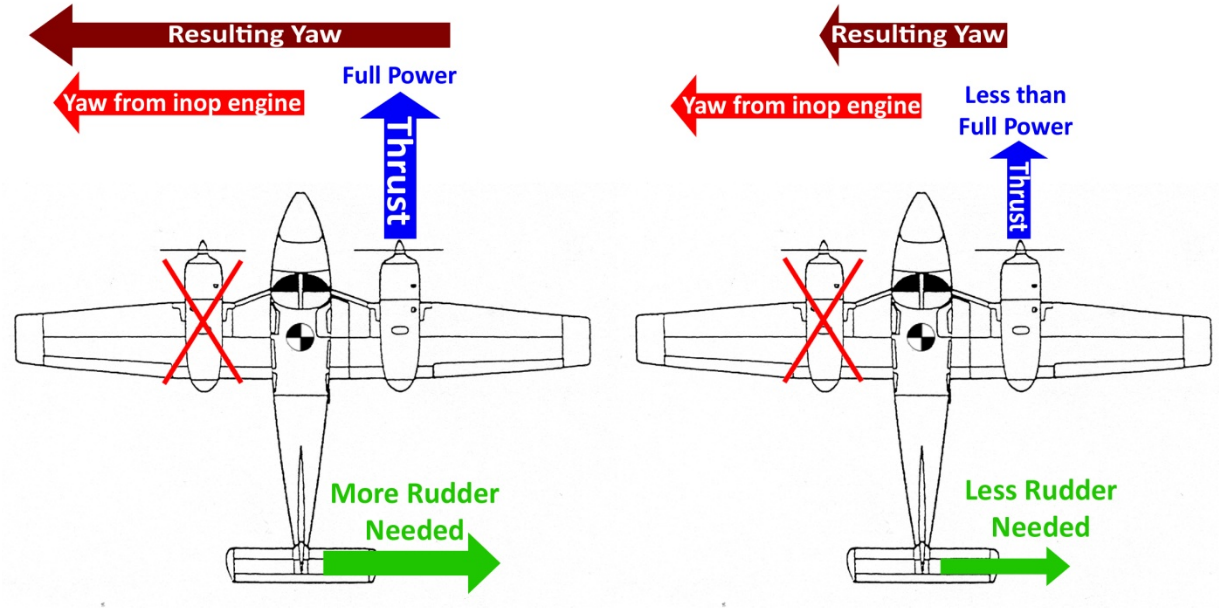
V_{MC} becoming a higher airspeed is bad because the airplane will lose directional control at a higher airspeed.
Things that make V_{MC} increase:

- Anything that will move the C.G. aft will make the rudder less effective.
    - Small arm to rudder = Smaller rudder moment = Rudder less effective.
- Anything that will cause more rudder to be used, making less rudder available to the pilot.

Performance of the airplane is not related to V_{MC} speed. Performance can be viewed as single engine climb performance or relating to the amount of drag on the airplane.

POWER

The more power (thrust) on the operating engine, the more rudder is needed to stop the resulting yaw. Using more rudder leaves less available to the pilot = V_{MC} speed increases as power on the operating engine is increased.

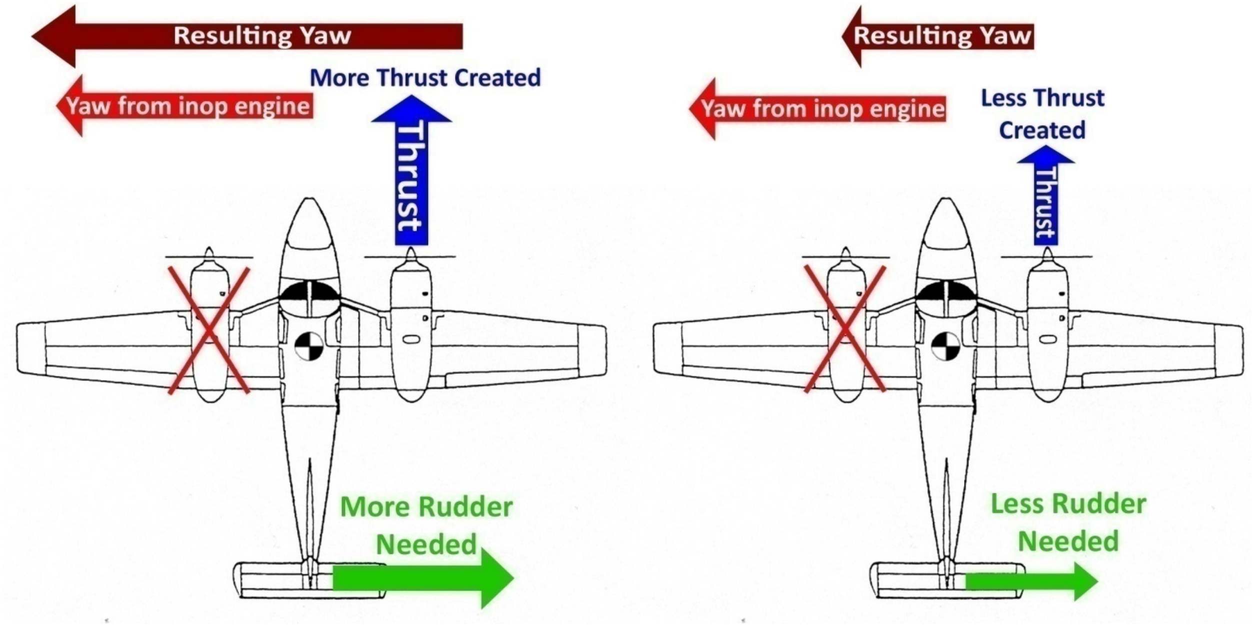


Performance increases as power is increased.

DENSITY ALTITUDE

As density altitude increases, temperature increases, pressure decreases, and/or humidity increases the output of the engine or thrust created by the engine decreases. The less thrust that is created, the less rudder input needed to oppose the yaw.

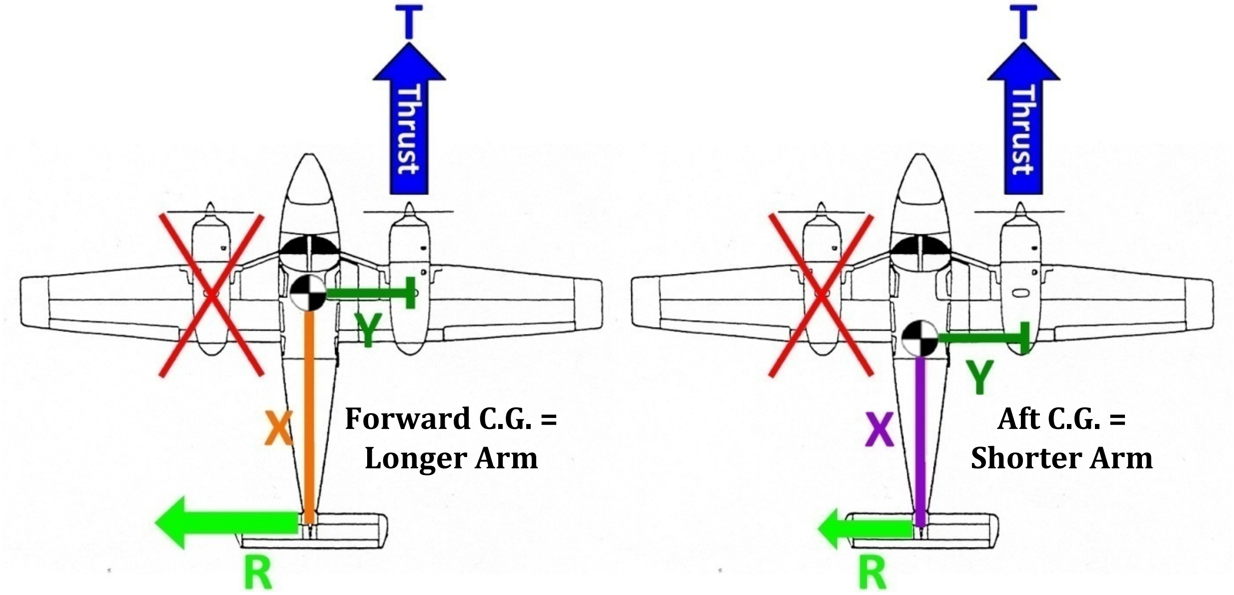
Using less rudder leaves more rudder available to the pilot. Therefore, V_{MC} decreases. So, as density altitude increases, temperature increases, pressure decreases, and/or humidity increases V_{MC} decreases.



Performance decreases as density altitude increases, temperature increases, humidity increases, and/or pressure decreases. With air being less dense, not only does the engine become less efficient, but the propeller and wings also have decreased performance due to having less air molecules available to make thrust and lift.

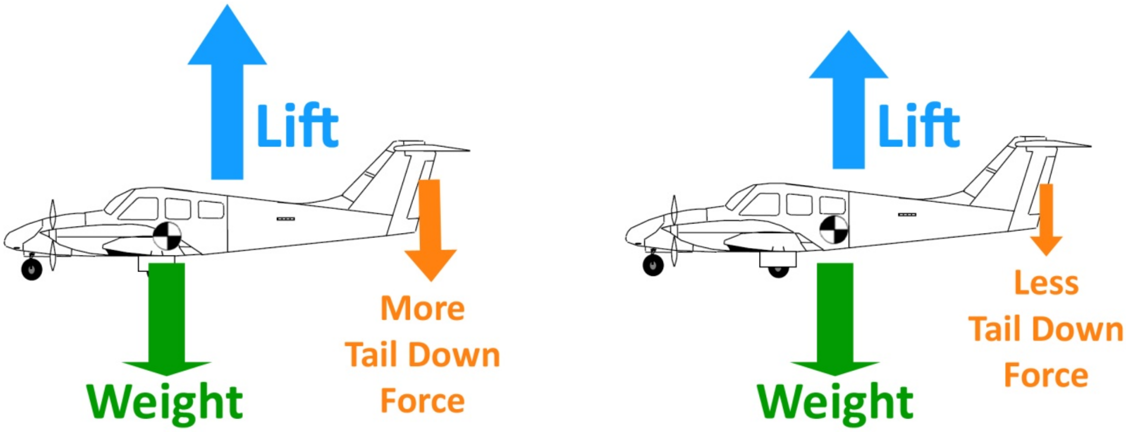
C.G. LOCATION

The C.G. location changes the length of the arm to the rudder: the longer the arm, the more effective the rudder; the more effective the rudder, the lower V_{MC}. As the C.G. moves forward, V_{MC} decreases; as the C.G. moves aft, V_{MC} increases.



Performance increases as the C.G. is moved aft. As the C.G moves forward, more tail-down force is needed to keep the airplane level. The more tail-down force needed, the more total lift is required. When more lift is created (airplane flying at a higher angle of attack), more drag is also created. The increase in drag causes the overall speed to decrease.

Total Lift Required = Weight + Tail Down Force



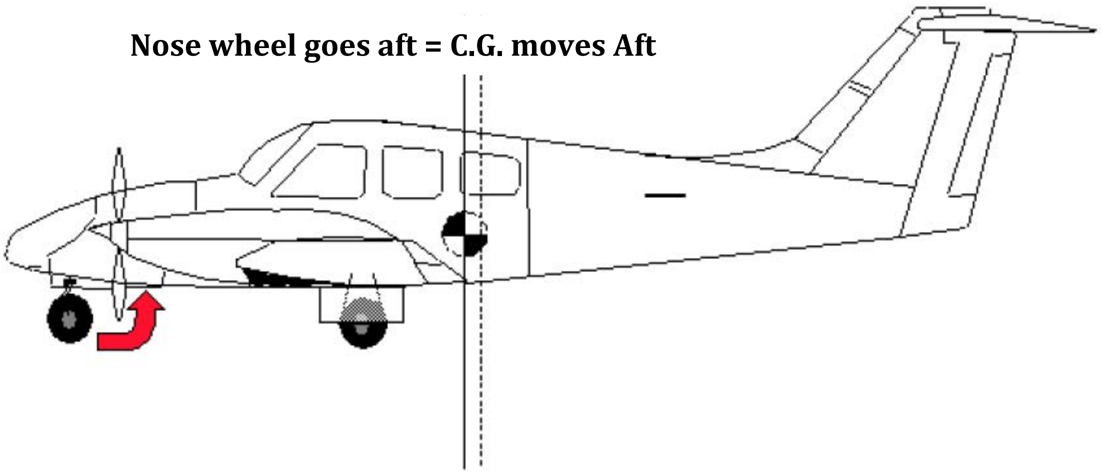
Effects of Forward C.G.

Rotation	More difficult	More weight toward front – harder to pull nose up.
Stall Speed	Higher	Forward C.G. causes higher AOA for level flight – more induced drag.
Cruise	Slower	Forward C.G. causes higher AOA for level flight – more induced drag.
Spin and Stall Recovery	Good	Forward C.G. helps make stall recovery easier.
Flare	More difficult	More weight toward front – harder to pitch nose up.
Endurance	Unchanged	Time aloft remains the same regardless of where the C.G. is located.
Range	Worse	Forward C.G. causes a higher AOA for level flight – more induced drag – slower airspeed.

Aft C.G. effects are just the opposite of the Forward C.G. effects.

GEAR POSITION

As the landing gear operates to retract or extend, the C.G. location moves in the direction of travel of the nose gear.



The change in C.G. affects V_{MC} speed just as stated before. In the extended (down) position, the landing gear can also act like the keel of a boat, giving the airplane a stabilizing effect. This stabilizing effect helps prevent a turn, thereby lowering V_{MC}.

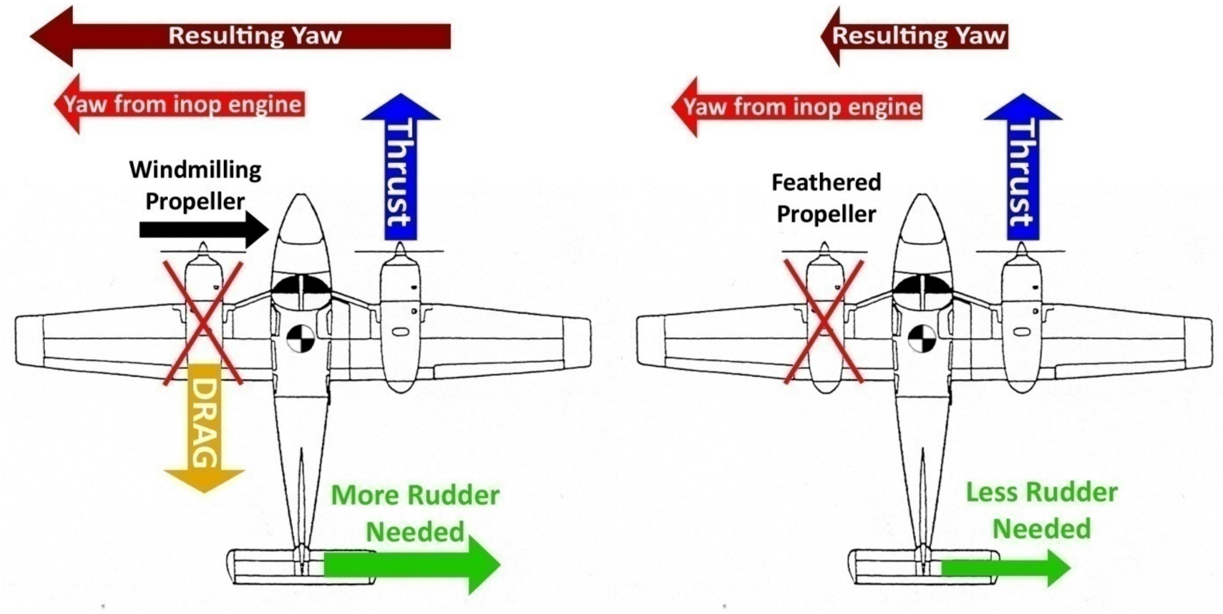
NOTE

In the current Piper Seminole POH/IM it is stated: "fuel burn off and gear movement do not significantly affect C.G. location (page 6-15)."

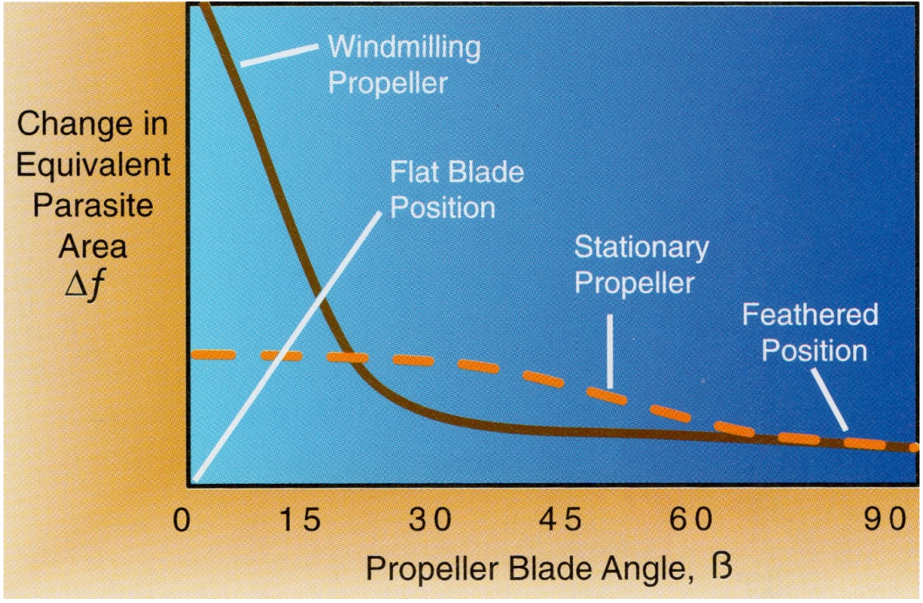
The landing gear extended (down) always decreases performance due to parasite drag.

PROPELLER WINDMILLING VS. FEATHERED PROPELLER

A windmilling propeller creates more drag than a feathered propeller. This extra drag adds to the yawing from a failed engine to make the total effect worse. This situation will require more rudder deflection to maintain directional control, which means that less rudder is available to the pilot, thereby increasing V_{MC}. Once the propeller is feathered the drag is reduced, thereby reducing V_{MC}.



Propeller Blade Angle vs. Parasite Drag



Jeppesen Multi-Engine Manual

A windmilling propeller decreases performance due to the parasite drag created by the propeller blades.

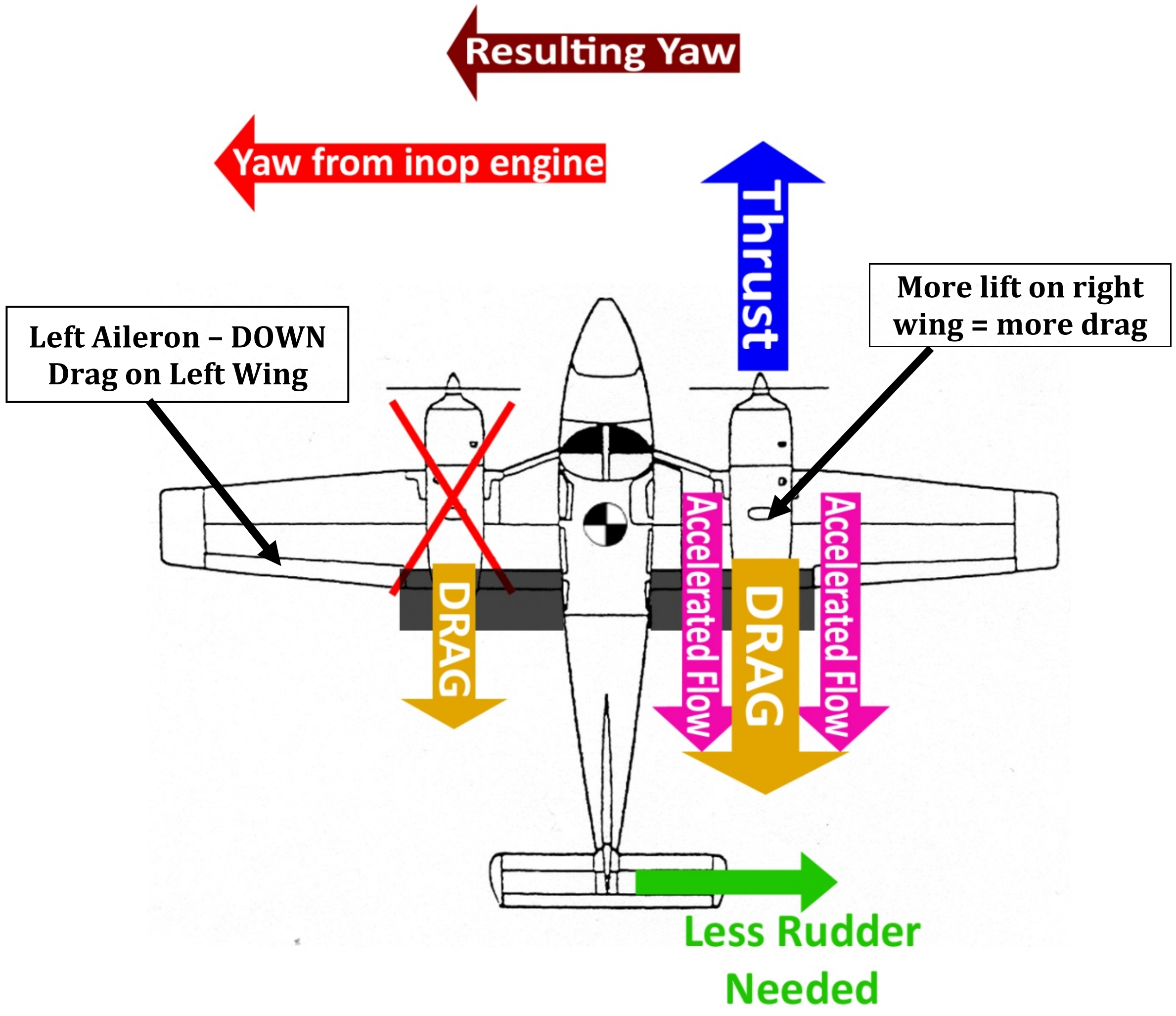
FLAPS DOWN

When the flaps are down the wings create more lift than if the flaps were up. However, when lift is created, drag is also created (as lift increase, drag increases).

The side with the operating engine is creating even more lift because of the accelerated air flowing over the wing. When the flaps are extended, the drag caused by the accelerated flow opposes the yaw caused by the inoperative engine allowing the pilot to use less rudder to maintain heading. Having more rudder available to the pilot lowers V_{MC}.

It should be noted more lift on the right wing will cause a roll to the left. If ailerons are used to counteract the rolling of the airplane, the drag from the adverse aileron yaw will actually increase the yaw towards the inoperative engine.

Flaps Down



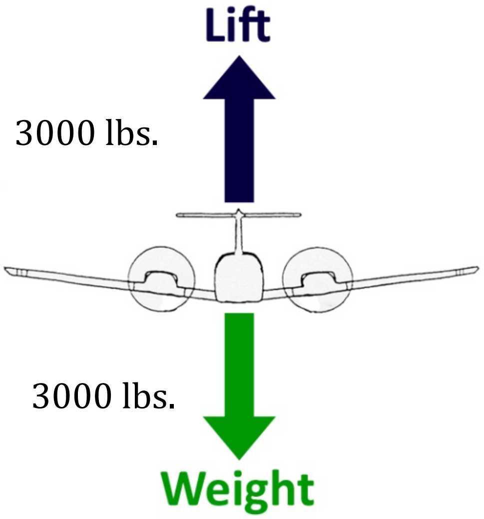
Because the flaps create more drag and the control surfaces will be deflected a greater amount, overall performance will decrease.

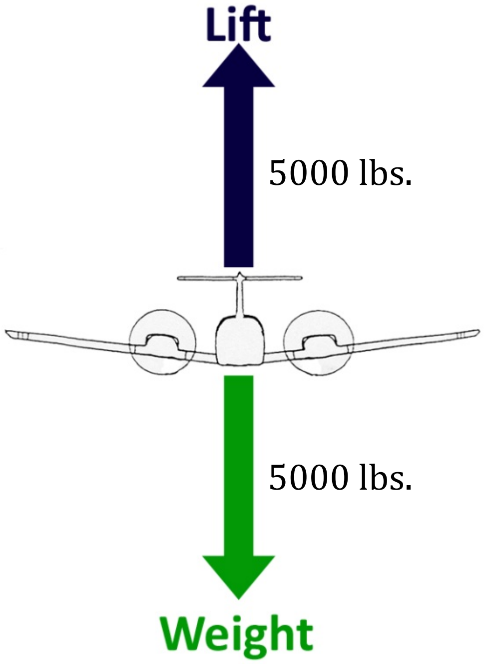
WEIGHT

The weight of the airplane determines the amount of total lift required by the airplane to maintain level flight. As the airplane is banked, the lift is separated into horizontal and vertical components of lift.

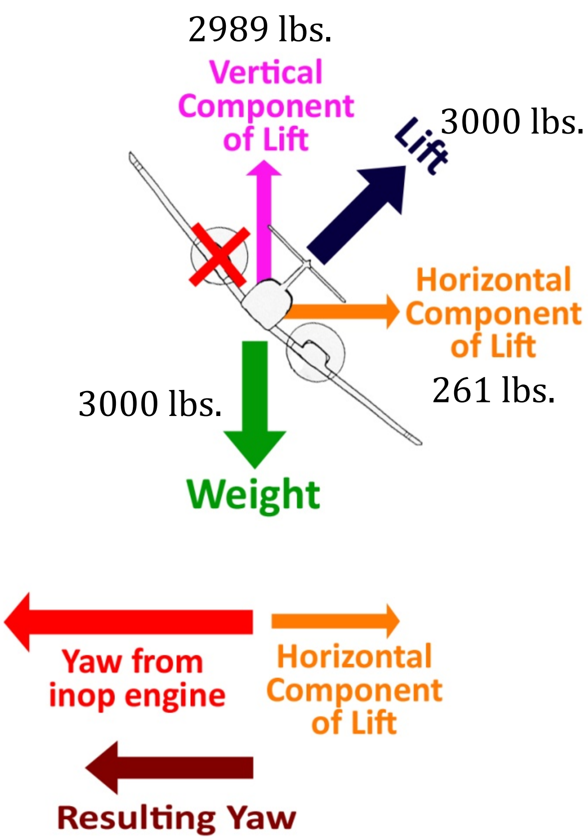
The horizontal component of lift (the force that causes the airplane to turn) will help oppose the yaw due to an inoperative engine. The more weight, the more horizontal lift is available to oppose the turn from the inoperative engine.

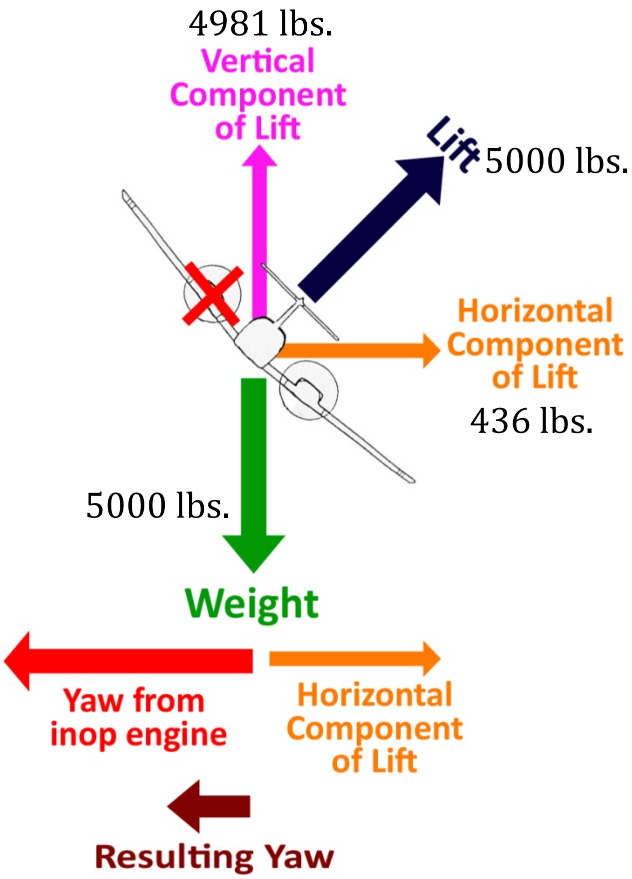
This means that horizontal lift can be used along with rudder to stop the turn. When more horizontal lift is available, less rudder is needed, which means more rudder is available to the pilot and V_{MC} decreases. So, as weight increases, V_{MC} speed decreases. As weight decreases, V_{MC} increases.





With a 5° Angle of Bank:





The larger horizontal component of lift on the heavier airplane will make the resulting yaw smaller. This also reduces the amount of rudder needed to maintain the airplane's heading.

A higher weight always lowers performance because it decreases the amount of excess thrust available. This is especially true during one-engine inoperative operations.

Fuel consumption will also lower the weight of an aircraft during flight, increasing V_{MC} and airplane performance. The amount it affects weight depends on the rate at which the fuel is consumed.

BANK ANGLE

Bank angle can affect V_{MC} and performance both positively and negatively. Just like the weight example, when an engine fails, the horizontal component of lift can be used to stop the yaw, but that is not the only affect of bank angle. Bank angle is related to VMC and performance in a few ways:

AMOUNT OF HORIZONTAL COMPONENT OF LIFT

This chart shows bank angle and the amount of lift in both the horizontal and vertical directions. Notice that at a 5° bank, a loss of 14 lbs. of vertical lift equals to a turning force of 314 lbs.

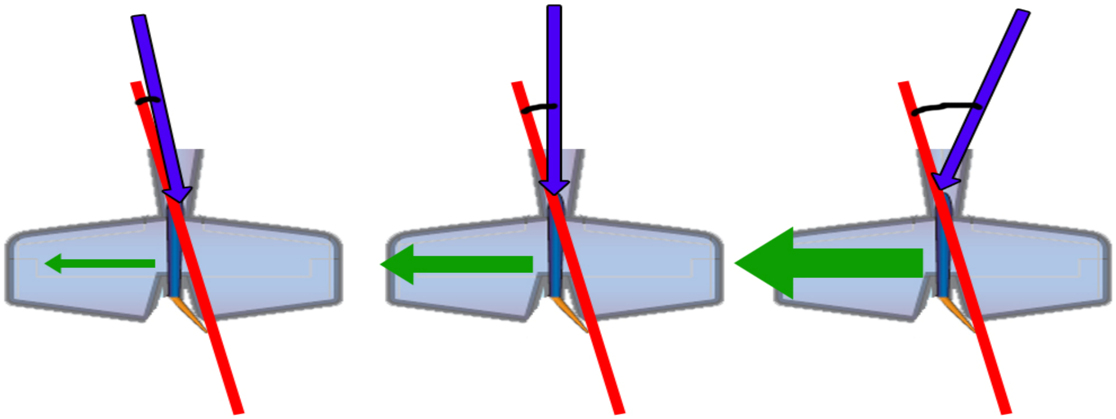
Bank Angle	Total Lift	Vertical Lift	Horizontal Lift
0	3600	3600	0
1	3600	3599	63
2	3600	3598	126
3	3600	3595	188
4	3600	3591	251
5	3600	3586	314
10	3600	3545	625
15	3600	3477	932
30	3600	3118	1800
45	3600	2546	2546
60	3600	1800	3118

$$\text{Vertical Component of Lift} = \text{Cos(Bank Angle)} \times \text{Weight}$$
$$\text{Horizontal Component of Lift} = \text{Sin(Bank Angle)} \times \text{Weight}$$

ANGLE OF ATTACK ON THE RUDDER – RUDDER EFFECTIVENESS

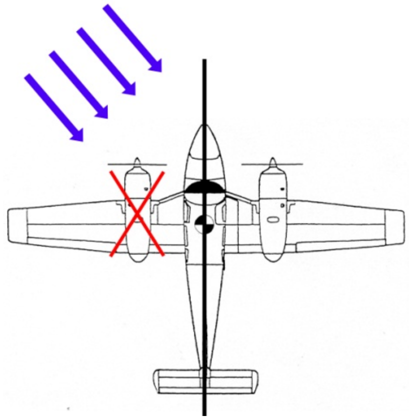
The angle of attack on the rudder determines how much force the rudder can create. It is dependent on the angle of the relative wind to the chord line of the rudder. The larger the angle of attack, the larger the force produced by the rudder. When the airplane is banked, rudder forces will act both in the vertical and horizontal directions.

Red = Chord Line of Rudder
Blue = Direction of the Relative Wind on Rudder
Green = Resulting Rudder Force

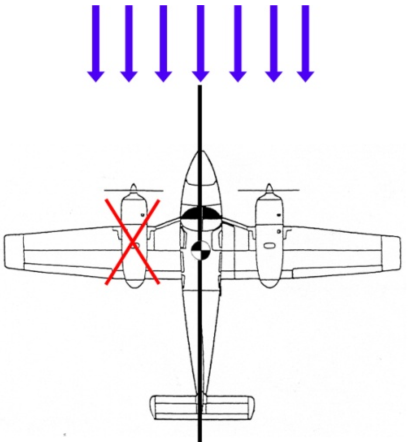


DIRECTION OF RELATIVE WIND – SLIPPING VS. COORDINATED

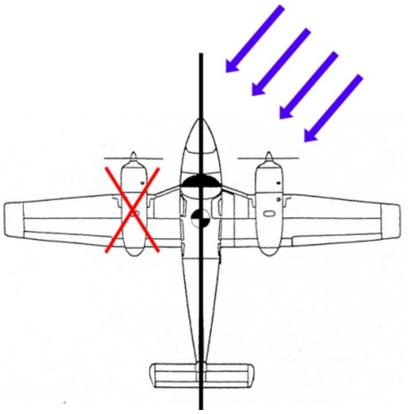
Anytime the relative wind is not parallel to the longitudinal axis of the airplane more drag is created.



Wings level or banked
toward inoperative engine
More Drag



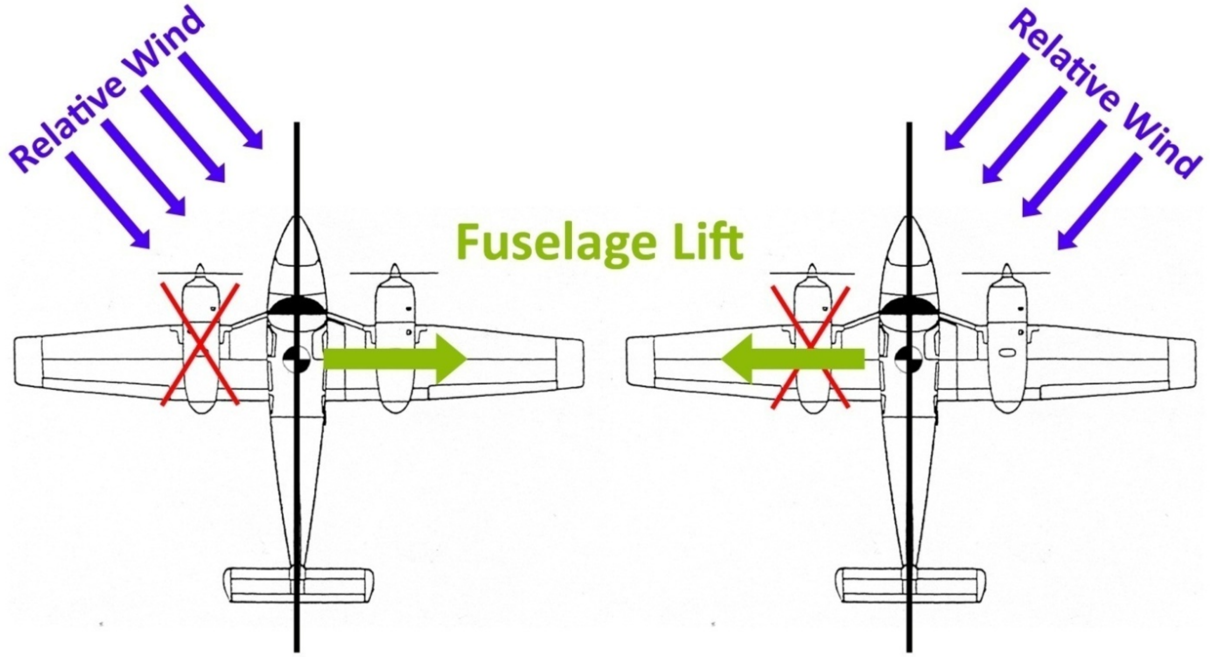
2°-3° Bank
(Zero Sideslip)
Least Drag



Wings banked more than 3°
toward operating engine
More Drag

AMOUNT OF FUSELAGE LIFT PRODUCED

Just like the wings, the fuselage produces lift. However, the fuselage is just not as efficient at making lift as the wings. Fuselage lift is more noticeable when the relative wind is not flowing directly parallel to the longitudinal axis of the airplane.

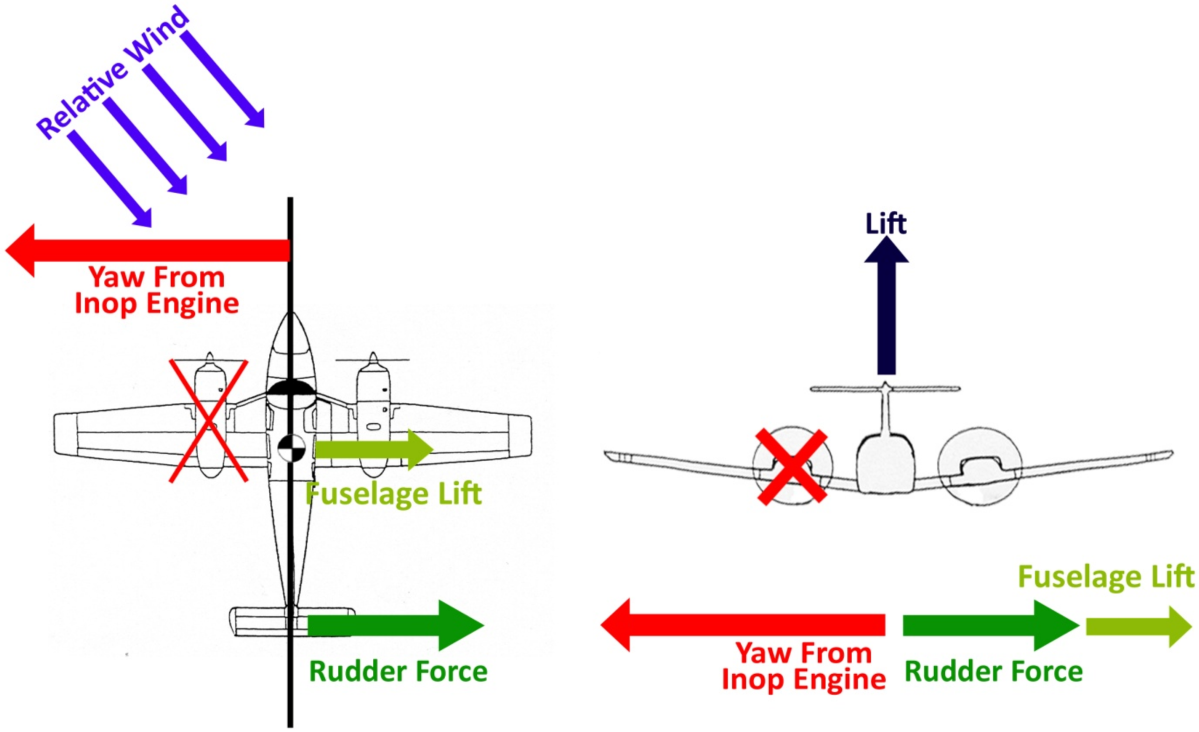


BANK ANGLE EXAMPLES

By putting all these factors together, it is possible to see the overall effects of bank angle and how these factors affect both V_{MC} and performance. To compare the effects of V_{MC} and performance it is necessary to use a few different examples. In the following examples, the airplane is maintaining a constant heading after experiencing a failed left engine.

0° OF BANK

In this example, only the rudder is used to stop the yawing moment from the inoperative engine and the wings are kept level.



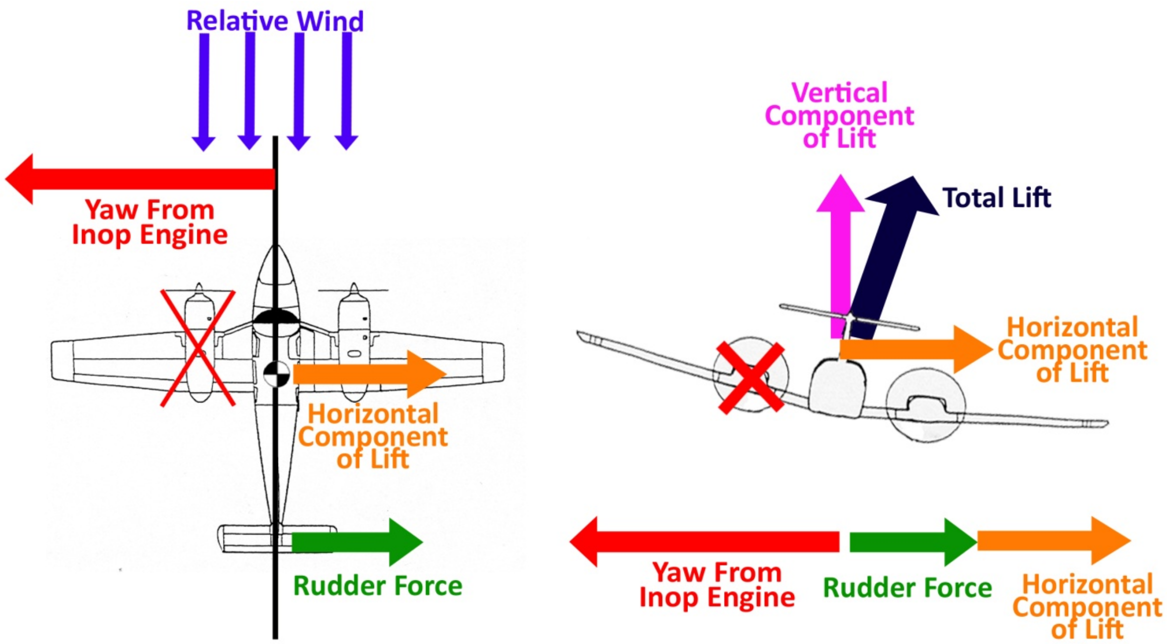
The relative wind, coming from the left of the nose, will cause the airplane to be in a slip. This causes the angle of attack on the rudder to be small and, therefore, makes it less effective.

It also creates fuselage lift in the direction opposite of the yaw from the inoperative engine. Since the angle of attack on the rudder is small, the amount of rudder required to maintain a constant heading is quite large. This makes V_{MC} a moderately high airspeed.

The slipping condition of the airplane will result in a moderate amount of drag which lowers overall performance.

2°-3° BANK TOWARD OPERATING ENGINE

In this example, both rudder and a small amount of bank are used to maintain a constant heading.



This bank angle results in a **Zero Sideslip** condition. A Zero Sideslip condition exists when the relative wind is directly parallel to the longitudinal axis of the airplane. This condition results in the minimum amount drag possible when an engine is failed.

V_{MC} speed will be lower in this case (compared to 0° bank) for two reasons:

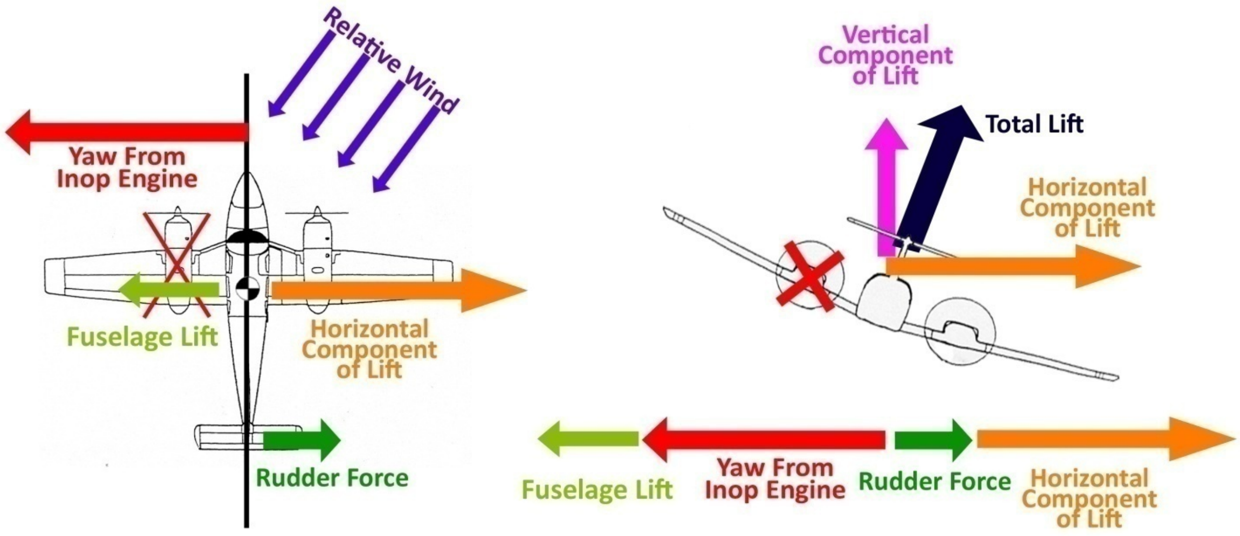
1. The angle of attack on the rudder is larger making it more effective.
2. The amount of rudder needed and used is less than in the 0° of bank scenario since it is more effective. Also, the horizontal component of lift is now helping to oppose the yaw from the inoperative engine (meaning less rudder will be required).

The result is more rudder is available to the pilot which will lower V_{MC}.

Performance will increase due to the smaller amount of drag.

8° BANK TOWARDS OPERATING ENGINE

In this example, a greater amount of bank toward the operating engine is used along with a lesser amount of rudder.

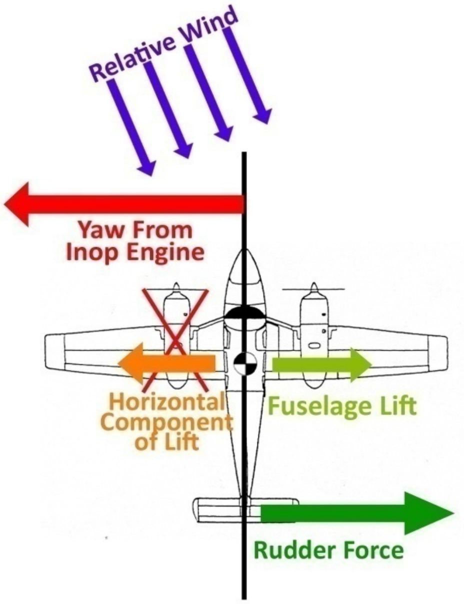


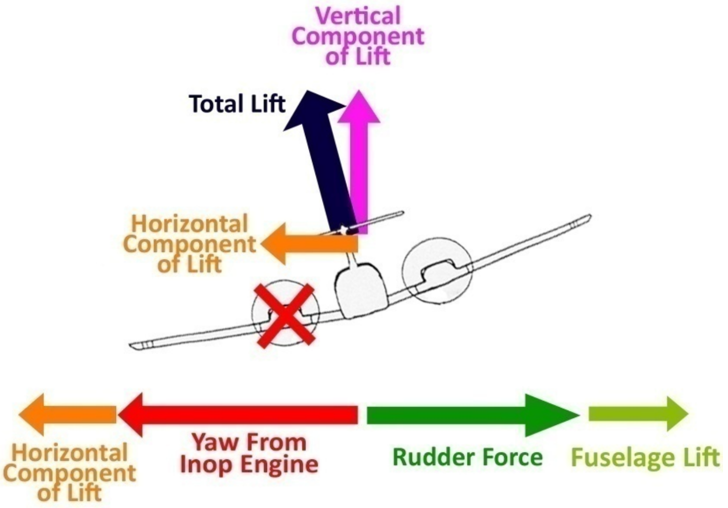
The direction of the relative wind will create a large angle of attack on the rudder. This makes it more effective resulting is less rudder input needed by the pilot. Also, the greater amount of horizontal lift means that less rudder will be needed to maintain heading. This results in a lower V_{MC}.

The performance of the airplane will decrease because the angle of the relative wind will result in a slipping condition that produces a large amount of drag on the airplane.

5° BANK TOWARDS INOPERATIVE ENGINE

In this example, the airplane is banked towards the **inoperative** engine.





Banking towards the inoperative engine will cause the horizontal lift from the wings to add to the yaw from the inoperative engine. The relative wind will create a fuselage lift that opposes the yaw. The angle of the relative wind with the rudder will create a small angle of attack making the rudder less effective. To maintain heading the pilot will have to use a very large amount of rudder. This increases V_{MC} significantly.

The performance of the airplane will decrease because the angle of the relative wind will result in a slipping condition and cause a large amount of drag on the airplane.

SUMMARY OF BANK ANGLE RELATING TO V_{MC} SPEED AND DRAG

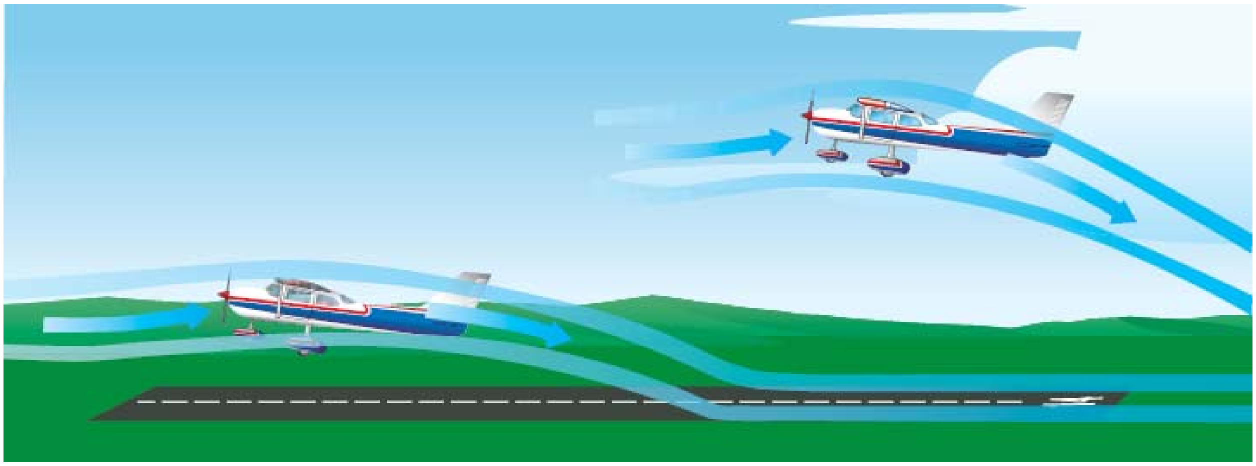
Bank Angle	V_{MC} Speed	Drag
5° bank towards inoperative engine	High	Moderate
0° bank	Moderate	Moderate
2°-3° bank toward operating engine (Zero Sideslip)	**Low**	**Minimum**
8° bank towards operating engine	Lower	High

CRITICAL ENGINE FAILURE

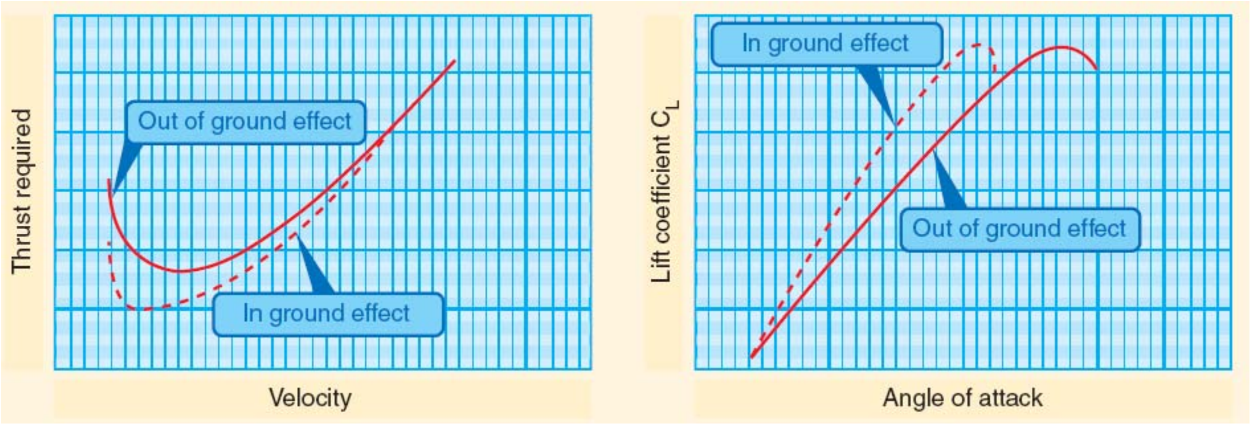
If the critical engine fails the resulting yaw and roll would be worse than if the non-critical engine had failed. The greater yaw and roll will require more rudder and control surface input to maintain directional control. The result is less rudder is available to the pilot which causes V_{MC} to increase. Performance will decrease because the greater control inputs and control surface deflection will cause a greater amount of drag to be created.

IN GROUND EFFECT

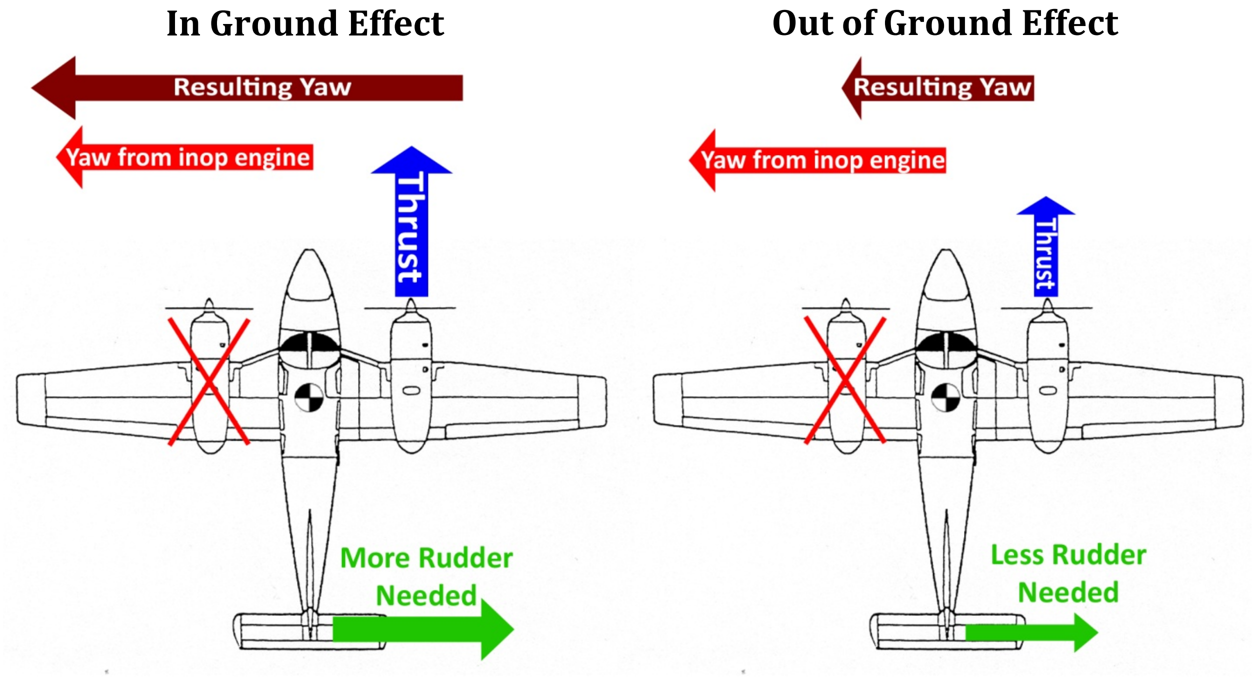
Ground effect is due to the interference of the ground surface with the airflow patterns around the aircraft in flight. As the wing encounters ground effect and is maintained at a constant amount of lift, there is a reduction in the upwash, downwash, and wingtip vortices.



The reduction in induced flow due to ground effect causes a significant reduction in induced drag, but causes no direct effect on parasite drag. As a result of the reduction in induced drag on the wings and propellers, **the thrust required at low speeds will be reduced**.



The reduction in thrust required means that the airplane will have extra thrust. The extra thrust on a good engine will cause a greater amount of yaw.



This is similar to the V_{MC} effect of power (i.e. the more yawing occurring in ground effect, requires more rudder to maintain heading). This condition increases V_{MC}.

Performance will increase in ground effect because of the reduction of induced drag.

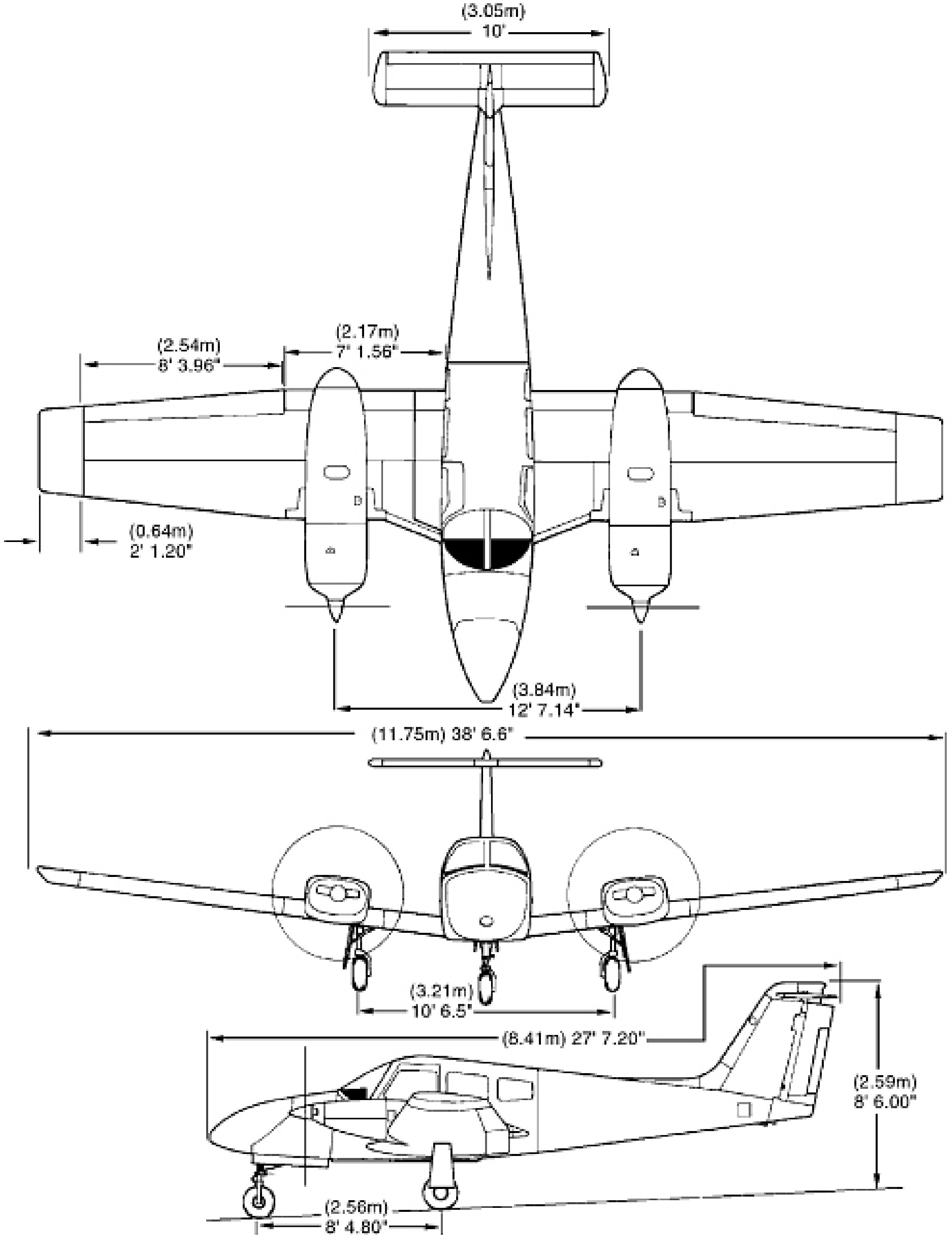
CHART OF FACTORS AFFECTING V_{MC}

Effect on	V_{MC}	Performance
Power Increase	Up – more yaw.	Up – more power.
Temp Increase	Down – less dense, less power, less yaw.	Down - less dense, less power.
Pressure Decrease	Down – less dense, less power, less yaw.	Down – less dense, less power.
Density Altitude Increase	Down – less dense, less power, less yaw.	Down – less dense, less power.
Bank Angle – 0° bank – no turn	Up – sideslip plane – less AOA on rudder because of sideslip airflow – less rudder effectiveness- more rudder needed.	Down – more drag – slipping.
Zero Sideslip – 2-3° bank – no turn	Middle – Use horizontal lift to stop turn – not slipping – more rudder effectiveness.	Up – less drag – zero slip.
Bank Angle – 5° bank – no turn	Down – plane turning toward good engine + rudder used to stop turn = slip toward good engine – high AOA on rudder.	Down – more drag – slipping.
Windmilling Propeller	Up – more drag, more yaw.	Down – more drag.
Feathered Propeller	Down – less drag, less yaw.	Up – less drag.
Aft C.G.	Up – less distance between rudder and C.G. – less rudder effectiveness.	Up- less tail down force required less induced drag Down – smaller arm on controls, less control effectiveness.
Heavier Weight	Down – more lift needed in level flight – more horizontal lift available during turn – helps prevent turn.	Down – more weight, more power required.
Flaps Down	Down – more induced drag from good engine side prevents yaw towards dead engine.	Down – more airflow over flap causes greater drag, causing increased yaw, causing increased roll, requiring more aileron to stop roll, creating more adverse yaw = more induced drag.
Gear Down	??? – depends on location of C.G. to gear & direction of travel – moves C.G. (V_{MC} Down – Keel Effect).	Down – more parasite drag.
Critical Engine Fails	Up – P-factor, Accelerated Slipstream, Torque make yaw worse.	Down – larger control inputs – more drag.
In Ground Effect	Up – less drag – more thrust available – more yaw.	Up – less drag.

V_{MC} down (slower) = good = more rudder available, or rudder more effective.
V_{MC} up (faster)= bad = less rudder available, or rudder less effective.

SEMINOLE SYSTEMS

DIMENSIONS



Minimum turning radius – 33 ft.

KEY NUMBERS

V-Speeds

V_{SO} – 55 KIAS
V_{MC} – 56 KIAS
V_S – 57 KIAS
V_X – 82 KIAS
V_{XSE} – 82 KIAS
V_{SSE} – 82 KIAS
V_{YSE} – 88 KIAS
V_Y – 88 KIAS
V_{FE} – 111 KIAS
V_{LO} – 109 KIAS
V_{LE} – 140 KIAS
V_{NO} – 169 KIAS
V_{NE} – 202 KIAS
V_A – 112 KIAS (2700 lbs.) to 135 KIAS (3800 lbs.)

Maximum Ramp Weight – 3816 lbs.
Maximum Takeoff Weight – 3800 lbs.
Maximum Landing Weight – 3800 lbs.
Maximum Baggage Weight – 200 lbs.

Total Fuel Capacity – 110 gallons
Total Useable Fuel – 108 gallons

AIRFRAME

The basic airframe is constructed of an aluminum alloy. The fuselage is a semi-monocoque structure, meaning both the internal supports and the metal skin share the load of the airplane.

The Seminole has an entry/exit door on the forward right (passenger) side of the fuselage, a cargo door on the aft right side of the fuselage, and an emergency egress available through the forward left (pilot) window.

The wings are semi-tapered and attached to the fuselage by one main spar and two auxiliary (front/rear) spars. The rear spar, in addition to taking torque and drag loads, provides a mount for flaps and ailerons.

ENGINE

The Piper Seminole is powered by two Lycoming four-cylinder O-360-A1H6 engines rated at 180hp at 2700 RPM.

The engines are carbureted, direct-drive, horizontally opposed, air cooled engines. The right engine model is called a LO-360-A1H6, with the L standing for left-turning. The 360 stands for the number of inches of cubic displacement in the cylinders, and the A1H6 stands as a manufacturer code for the type of accessories used on the engine and the type of propeller mount on the front of the engine.

Each engine is equipped with an oil cooler with a low temperature bypass system and engine mounted oil filter. The bypass system only lets oil flow through the oil cooler if the oil is hot enough to need to be cooled.

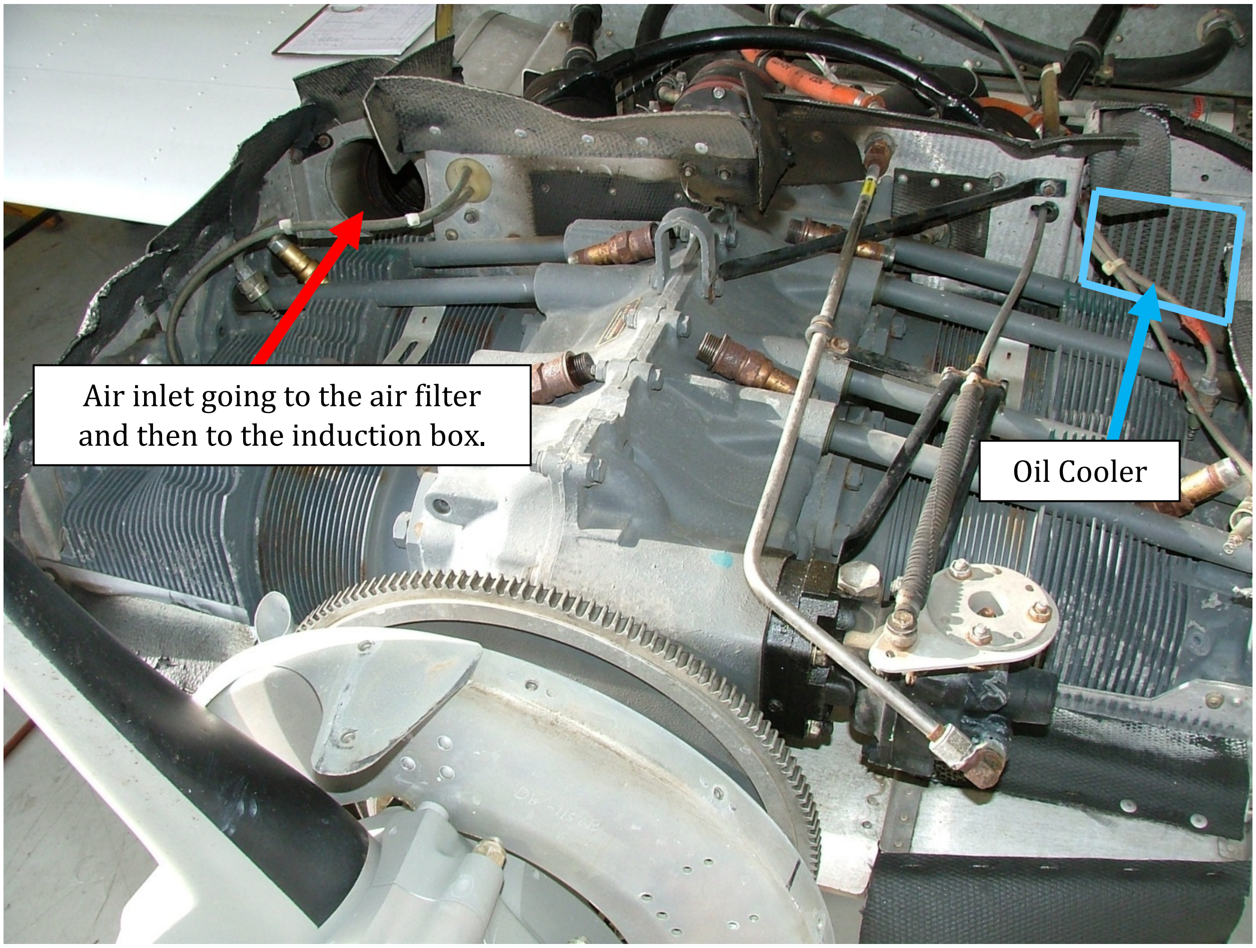
The oil system can hold a maximum of 8 quarts and be run on a minimum of 2 quarts. ERAU requires a minimum of 6 quarts before flight. Each engine has its own specific dipstick and they cannot be interchanged. Each dipstick has the words “LEFT ENGINE” or “RIGHT ENGINE” stamped on it (as shown below).

Air used for combustion goes into the engine through an air filter and then through the induction air box mounted on the bottom of the engine. This induction air box has a manually operated two-way valve that allows the carburetor to receive either:

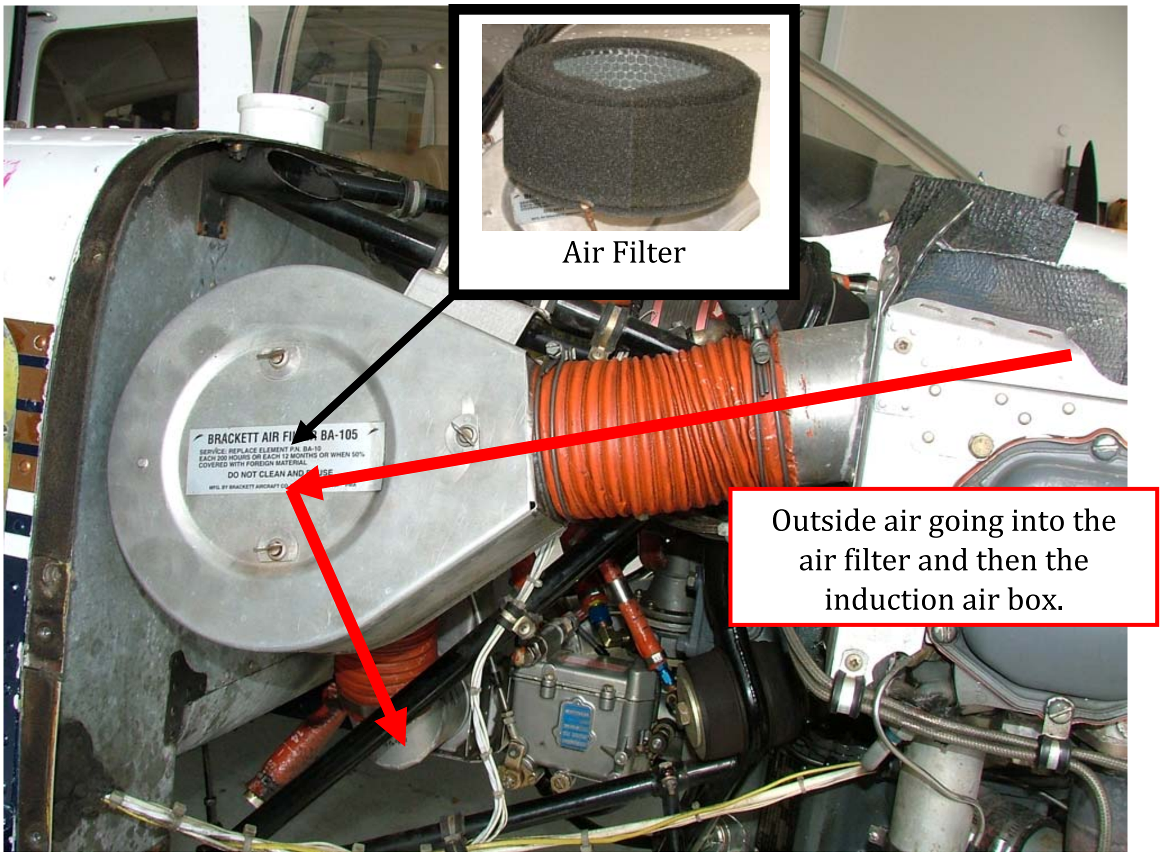
1. Induction air - through the air filter
2. Carburetor Heat – unfiltered air heated by the exhaust of the airplane through a shroud. (This heating of the air is accomplished by the same principle as the cabin heat system of a Cessna 172 or Piper Arrow.)

The carburetor heat setting must not be selected during ground operations to avoid dust or other contaminants that might enter the induction system and then the engine. The primary air source (through the air filter – Carburetor Heat off) should always be used for takeoff. If the Carburetor Heat is turned on, the heated air used by the engine is less dense than the outside air and will result in a drop in power produced by the engine.

View of the top of the engine

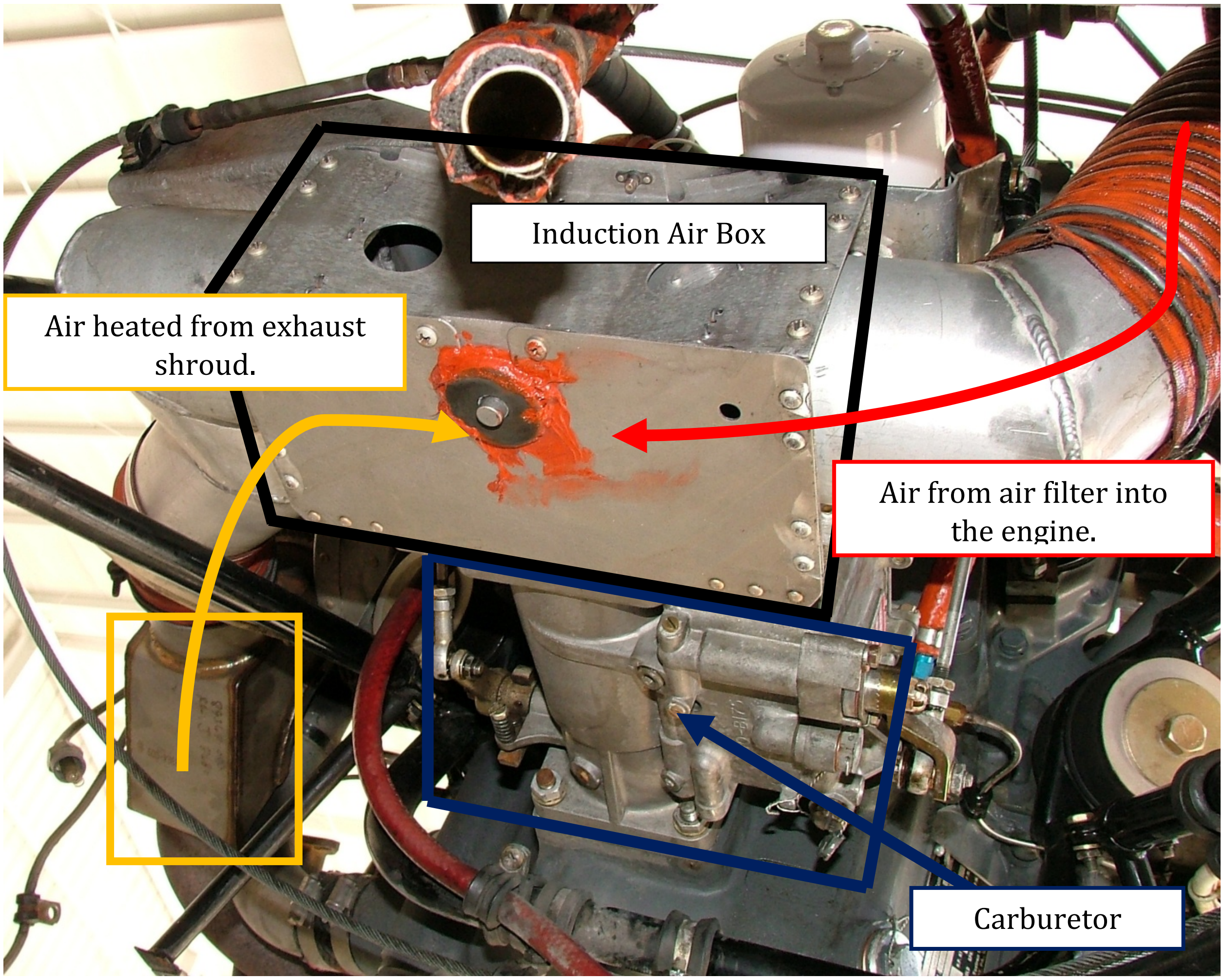


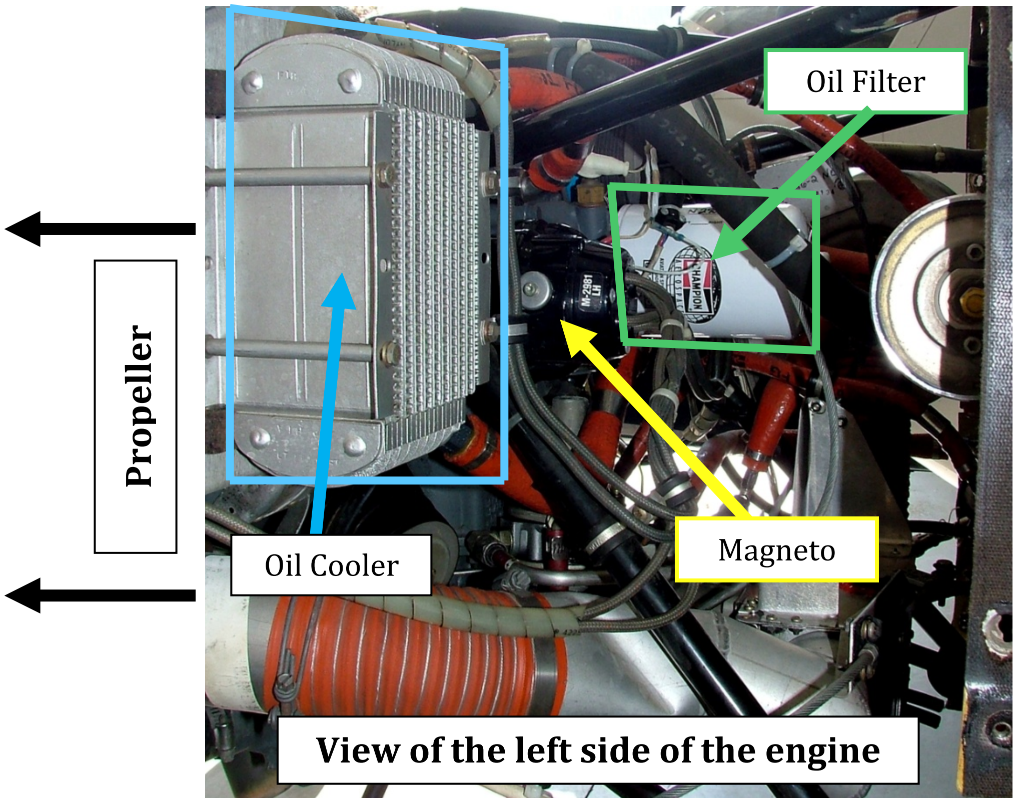
View of the right side of the engine



Outside air going into the air filter and then the induction air box.

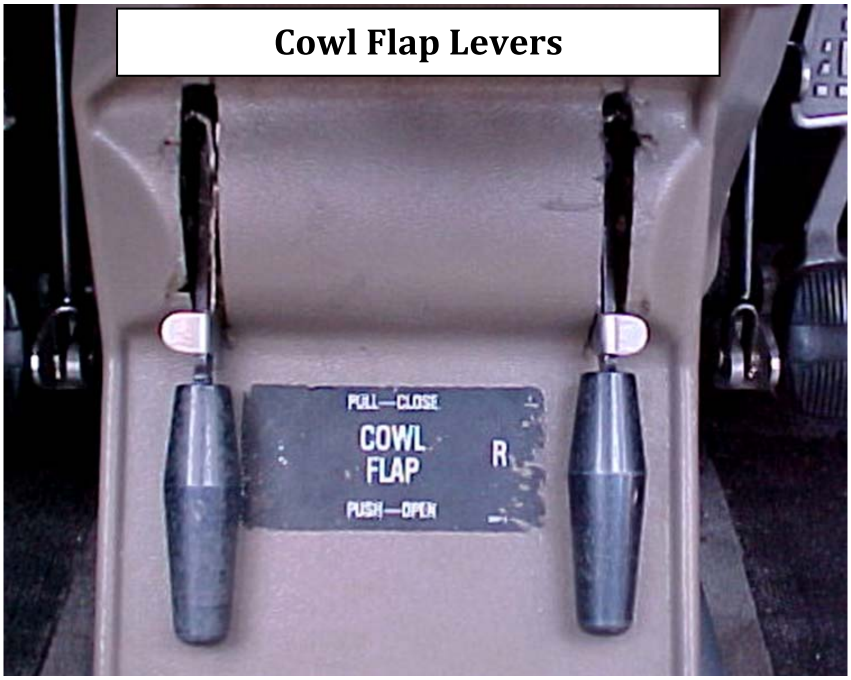
View of the bottom of the engine looking towards the propeller





COWL FLAPS

Each engine has a manually operated cowl flap which is used to change the amount of air flowing through the engine cowling. This air will cool the engine and keep it at normal operating temperatures. The cowl flaps have three positions (open, intermediate, and closed) and must be unlocked by pushing the metal lever in to move the cowl flap lever. Push down to open the cowl flaps, pull up to close.



Cowl Flap underneath the engine cowling

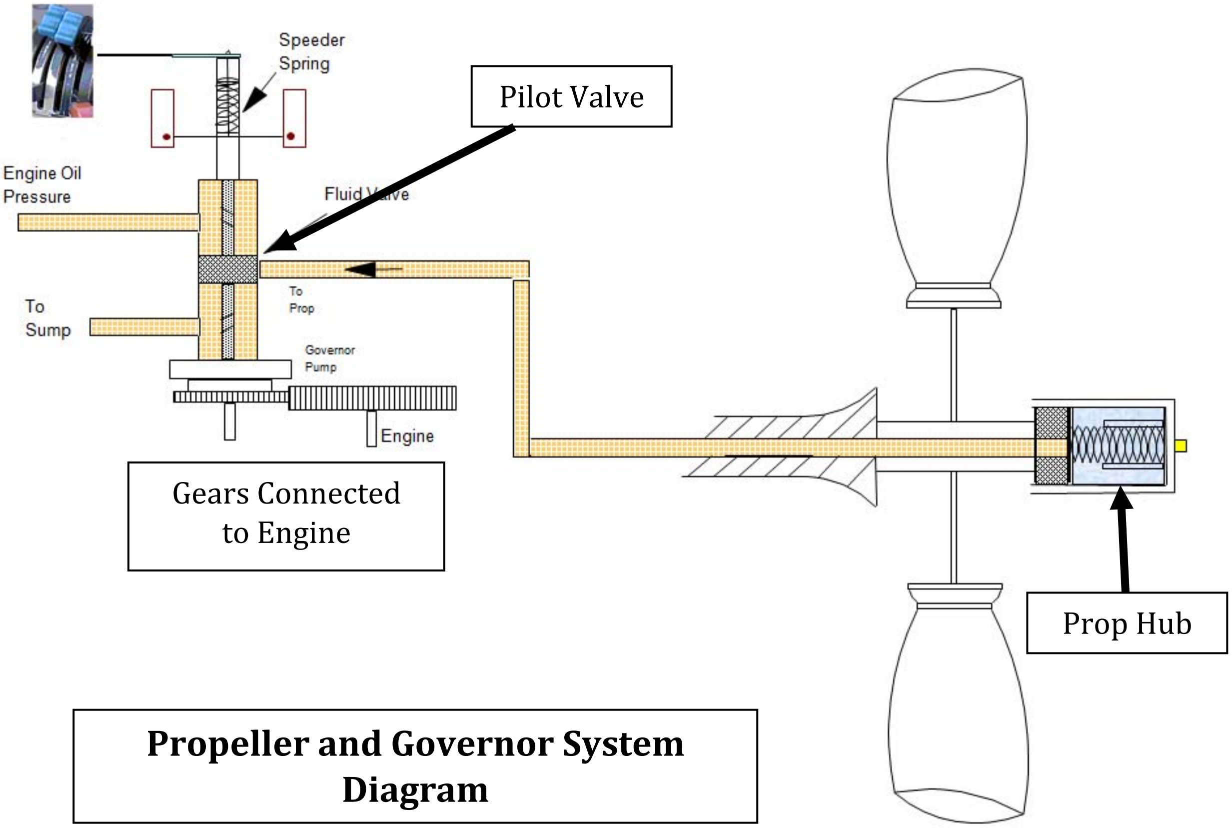
PROPELLER

The Seminole has counter-rotating propellers that provide balanced thrust during takeoff and climb and eliminate the critical engine factor in one engine inoperative flight.

The propellers are two-bladed, constant-speed, controllable-pitch and full-feathering Hartzell propellers. Propeller pitch is controlled by oil, a hub spring, counterweights, and nitrogen pressure. Governors supply engine oil at various pressures to the propeller hub to maintain constant RPM settings. Each governor controls engine speed by varying the pitch of the propeller to match load torque to engine torque in response to changing flight conditions.

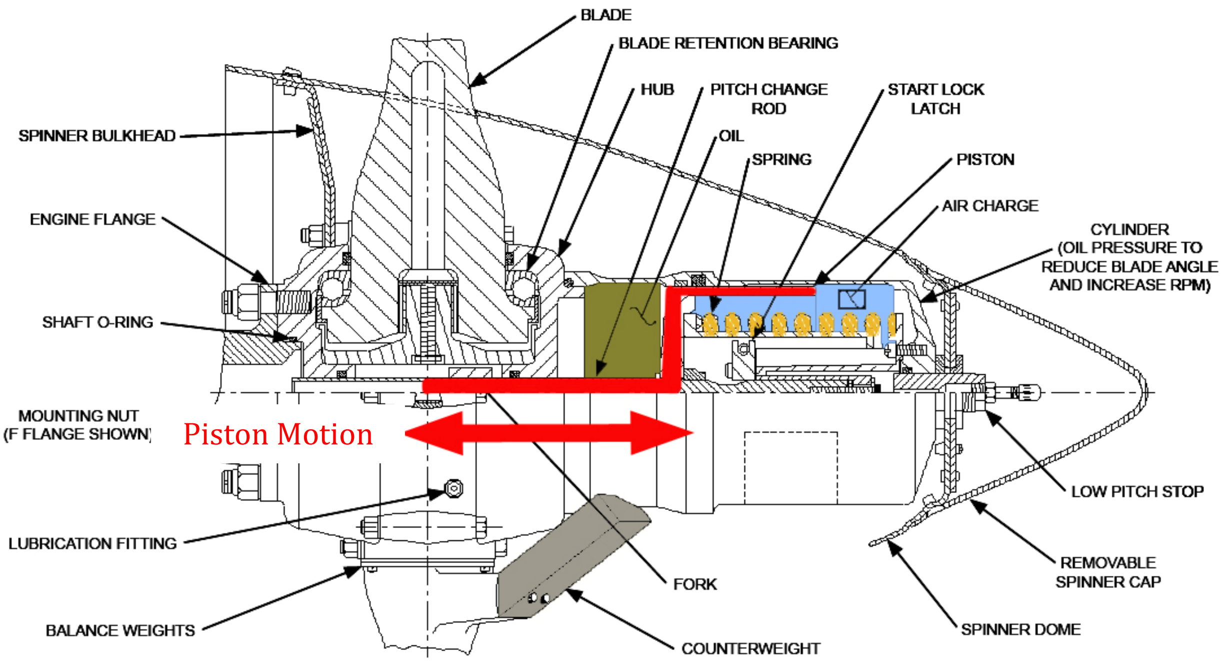
Blade Angle	RPM Speed	Forces acting on propeller
Low Pitch	High RPM	Oil Pressure
High Pitch and Feather	Low RPM or Feather	1. Nitrogen 2. Hub Spring 3. Counterweights

Feathering is accomplished by moving the propeller control full aft into the detent position. **Feathering takes approximately 10-17 seconds.** Unfeathering accumulators store engine oil under pressure from the engine, which is released directly to the governors for propeller unfeathering. **Unfeathering takes 8-12 seconds**, depending on oil temperature. A feathering lock, operated by centrifugal force, prevent feathering during engine shutdown by making it impossible to feather anytime the engine speed falls below 950 RPM. If there is no oil pressure in the engine and the engine speed is above 950 PRM the propeller will feather.

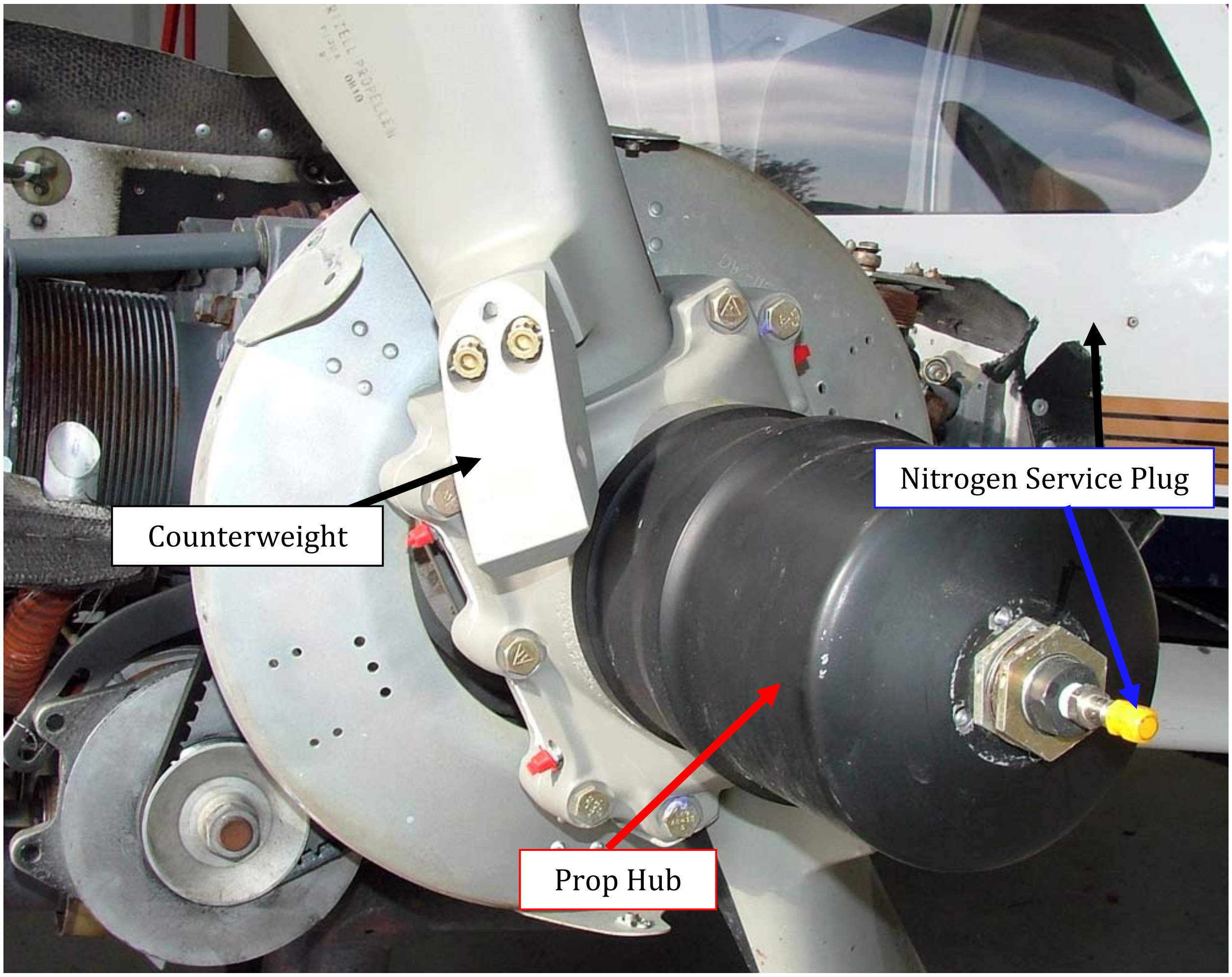


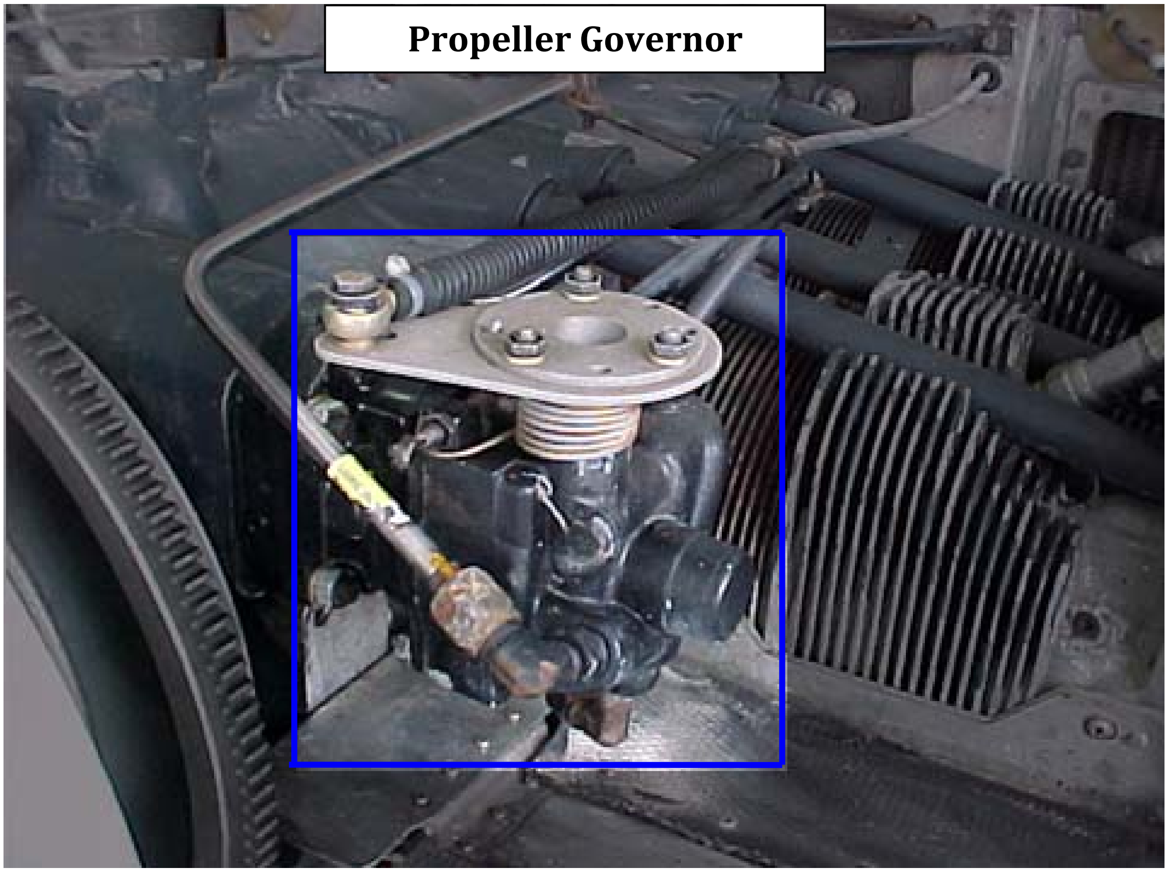
Propeller and Governor System Diagram

Propeller Hub Diagram

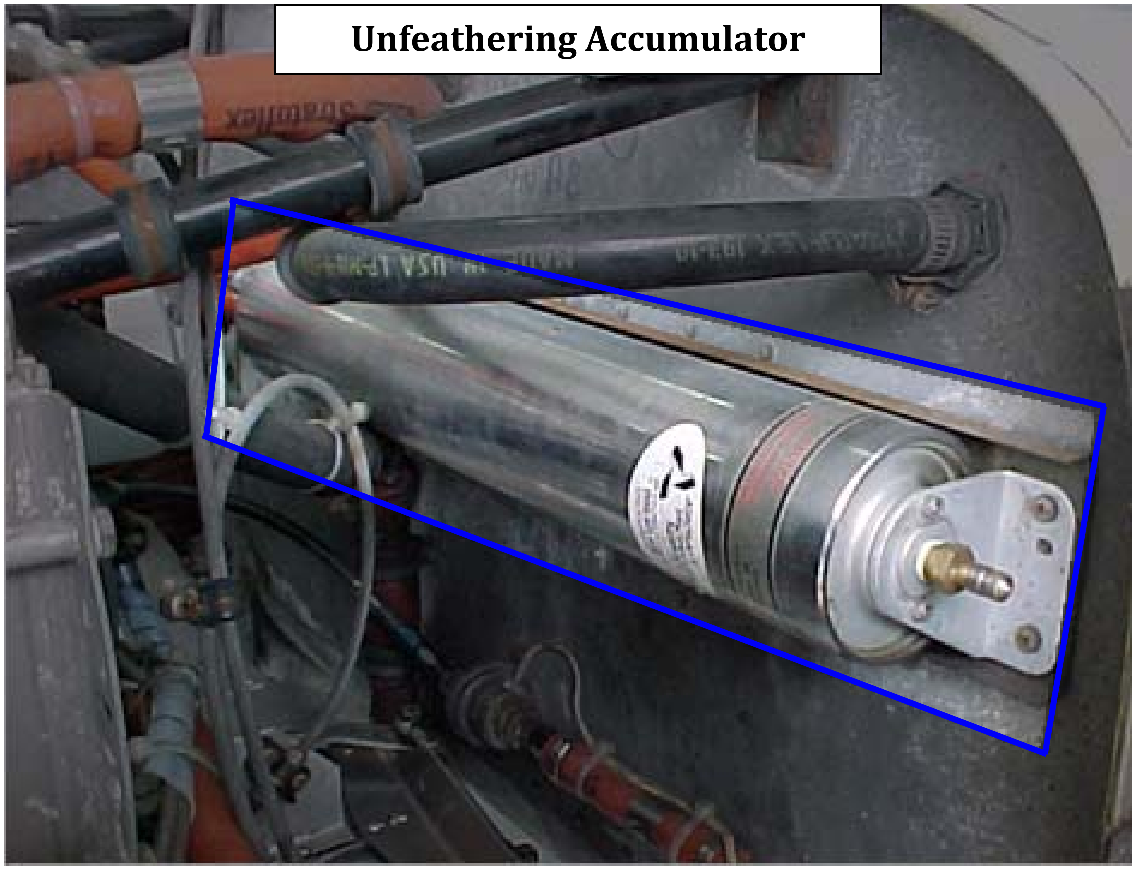


Propeller Hub with Spinner Removed



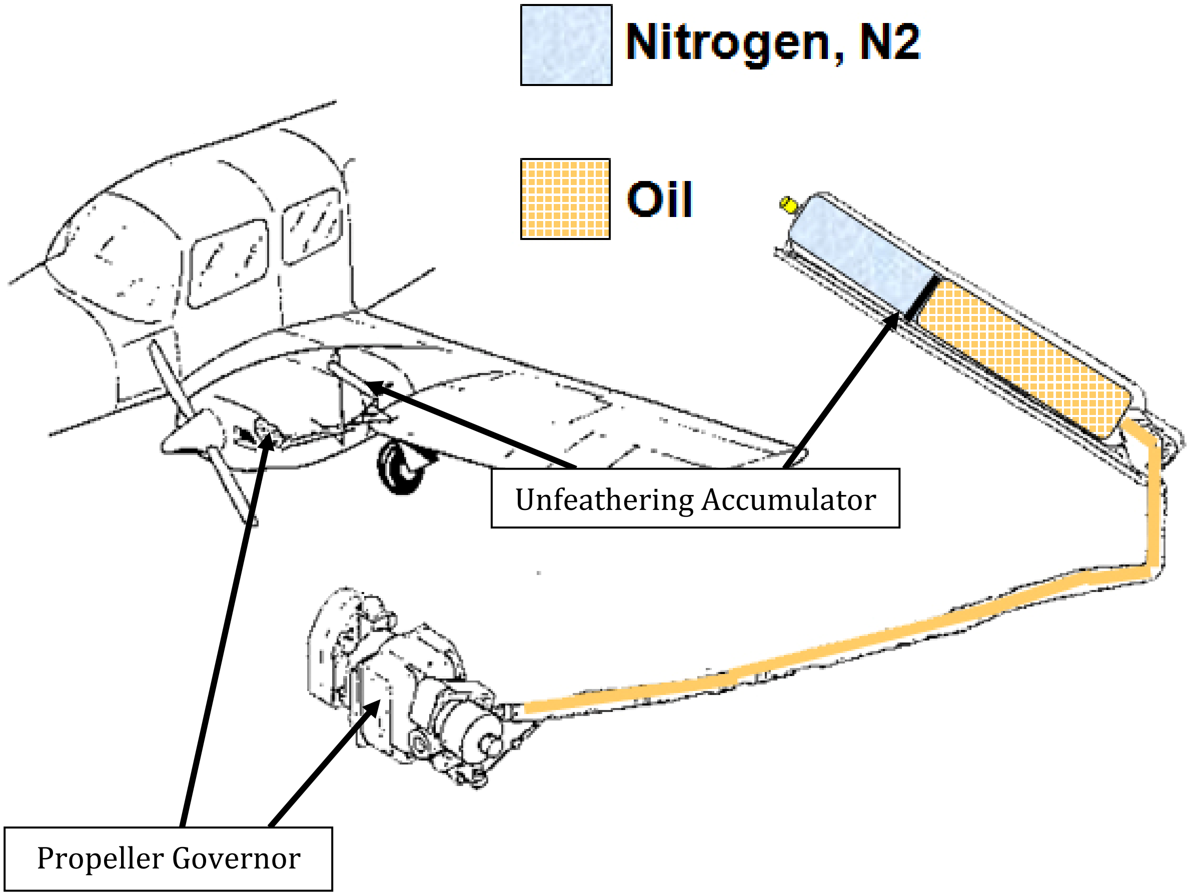


Propeller Governor



Unfeathering Accumulator

Propeller Governor and Unfeathering Accumulator Locations



LANDING GEAR

The landing gear is electrically activated and hydraulically actuated. The gear system uses an electric 12-volt, reversible pump to move hydraulic fluid. The hydraulic fluid flows in and out of an actuator that, in turn, raises and lowers the landing gear.

The landing gear pump is located behind the baggage compartment aft bulkhead (a removable plastic panel). **Landing gear extension or retraction takes 6 to 7 seconds.** There are also a series of up-limit, down-limit, and squat switches that control the system.

Gear Pump and Hydraulic Fluid Reservoir Located Behind the Baggage Compartment

When raising or lowering the landing gear, the hydraulic pump will activate and move hydraulic fluid from one side of each landing gear actuator to the other. This fluid motion moves a piston connected to an actuator rod that is connected to the appropriate landing or nose gear. The main gear actuators are located near the wheels under each wing.

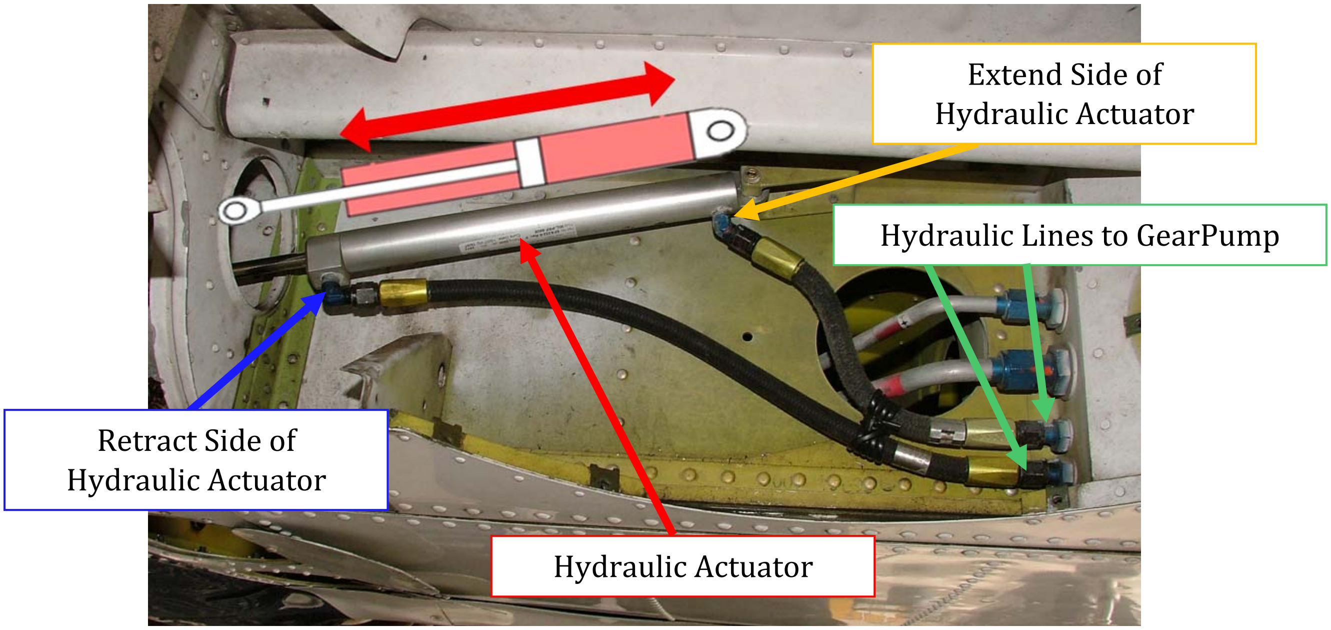
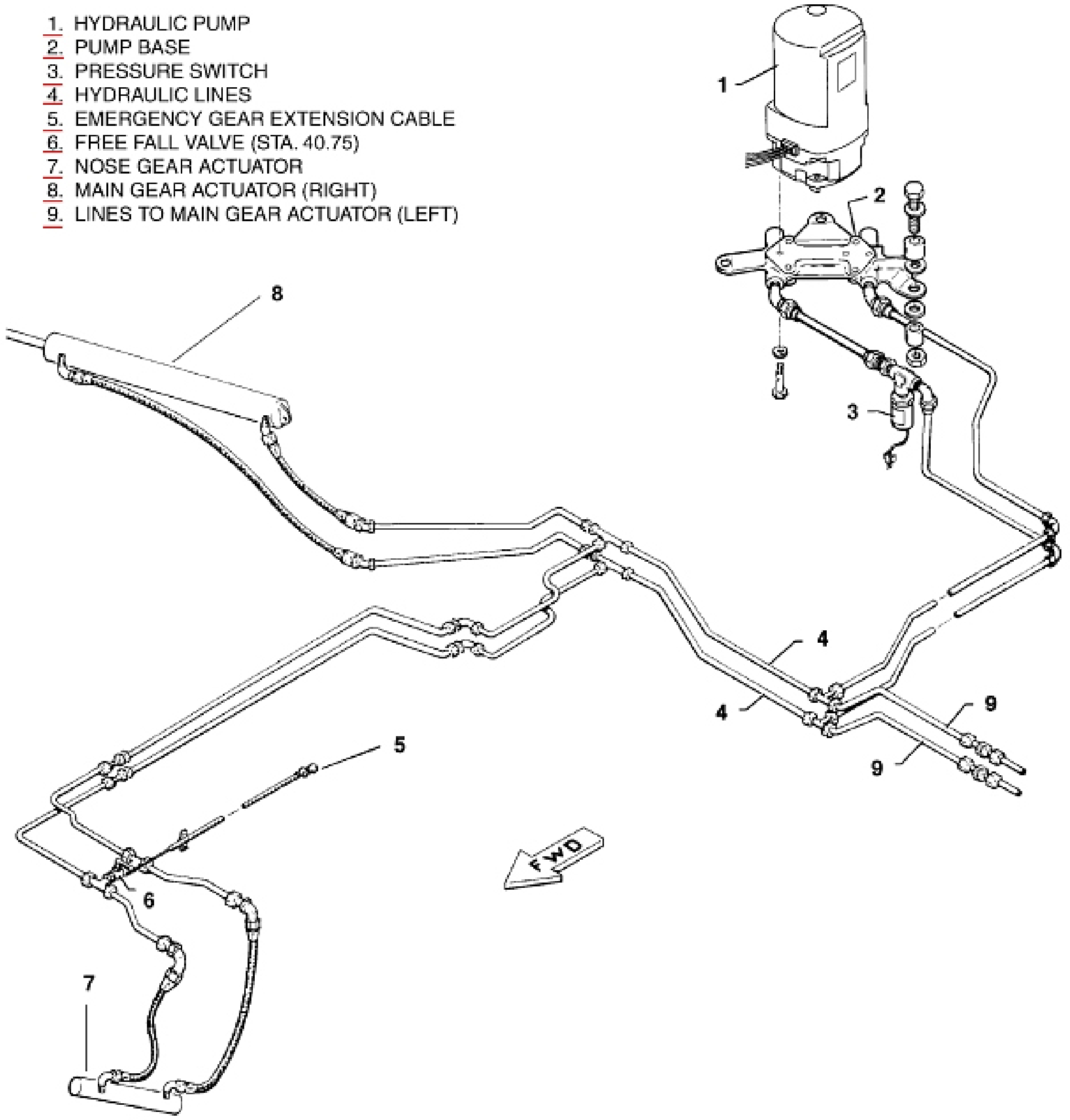


Diagram of Hydraulic Pump, Lines and Actuators



Landing Gear Operating Speeds

Maximum extension speed – 140 KIAS

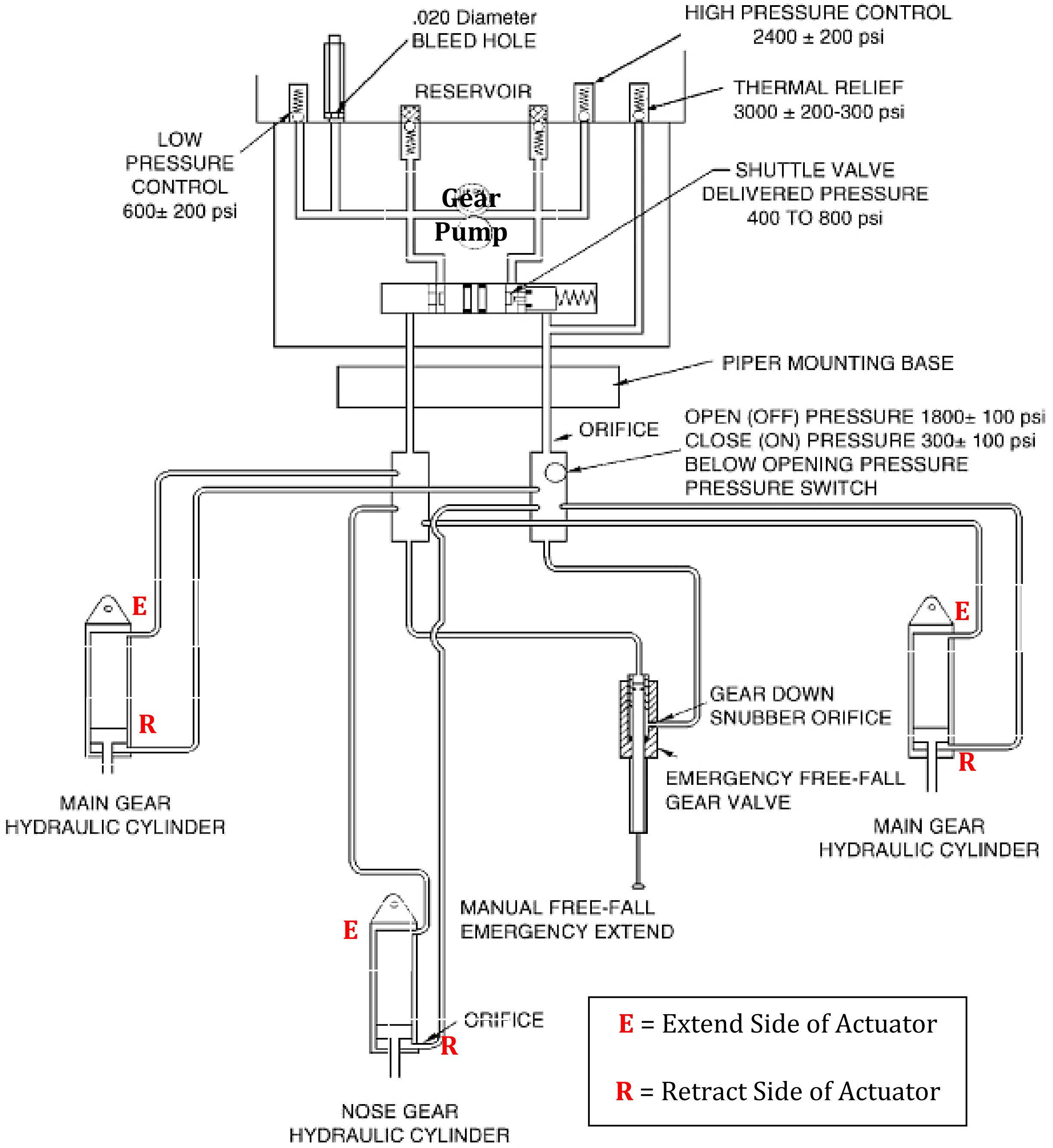
Maximum retraction speed – 109 KIAS

This speed is slower than extension because the nose wheel will unlock and ram air will push the nose wheel back into the wheel well. Any faster speed and it could damage the nose gear.

Maximum Emergency Extension Speed – 100 KIAS

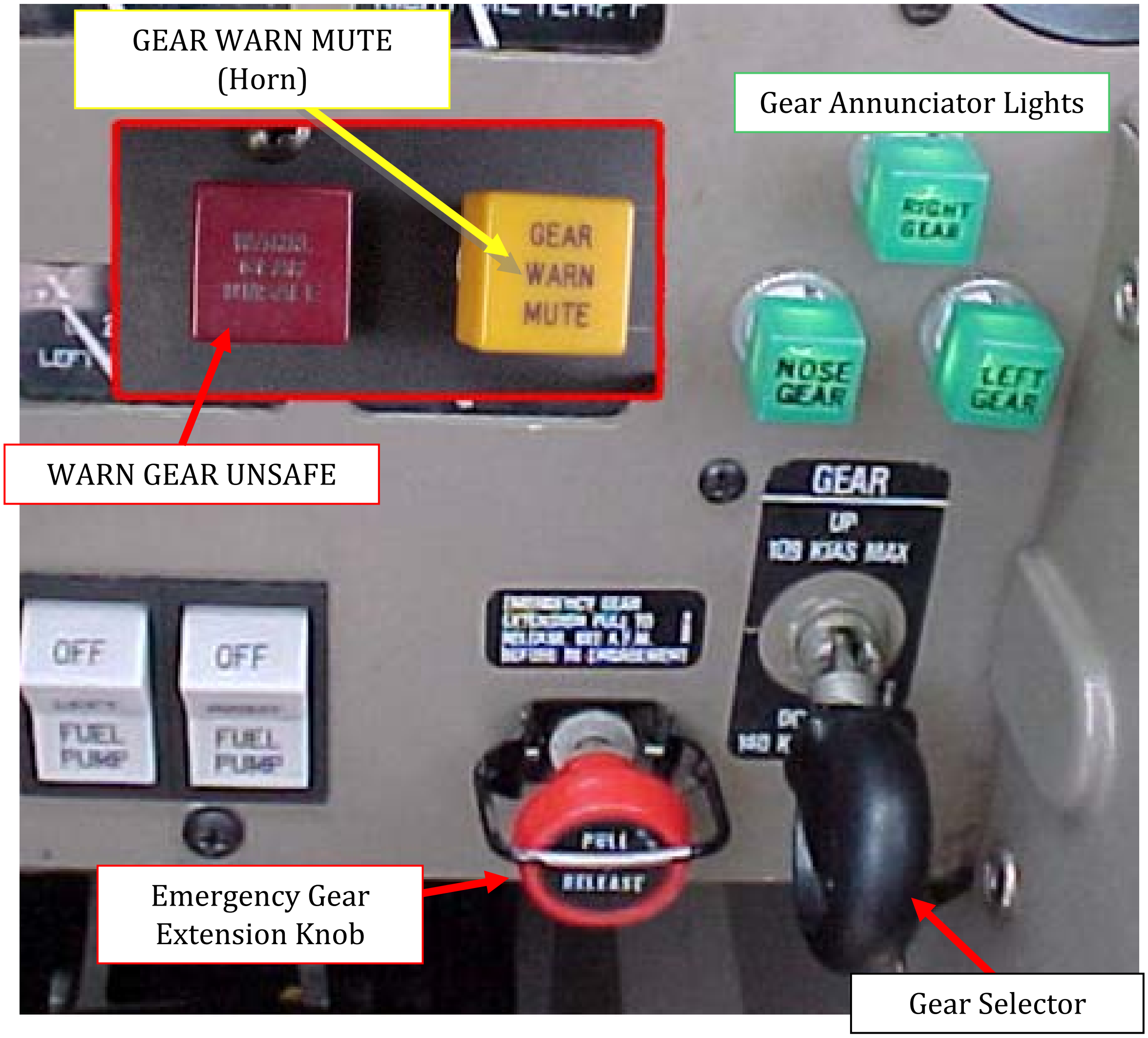
This speed is slow to allow the nose wheel to go forward into the oncoming air. There is also a large spring to help assist the nose wheel to extend forward.

Below is another diagram of the gear system. The pressures labeled are NOT important to memorize. A description of what the pressure control and relief valves do will be given later in this guide.



Each main gear or the nose gear has an up-limit switch and a down-limit switch to sense gear position. The left and right main gears have a squat switch. A squat switch determines if the airplane is airborne or still on the ground. The left squat switch prevents accidental gear retraction on the ground, while the right squat switch activates the stall warning horn and starts the maintenance time (equivalent of Time in Service in the Seminole). When the gear is retracted, it is held in the UP position only by hydraulic pressure. When the gear is fully extended (DOWN), it is locked down by a down-lock (called a "J-Hook" because of its shape), a spring that keeps tension on the J-Hook, and an over-center joint which helps keep the gear down in the event of a side-loaded landing. There are also mirrors mounted on the engine nacelles to allow visual confirmation that the nose wheel is extended.

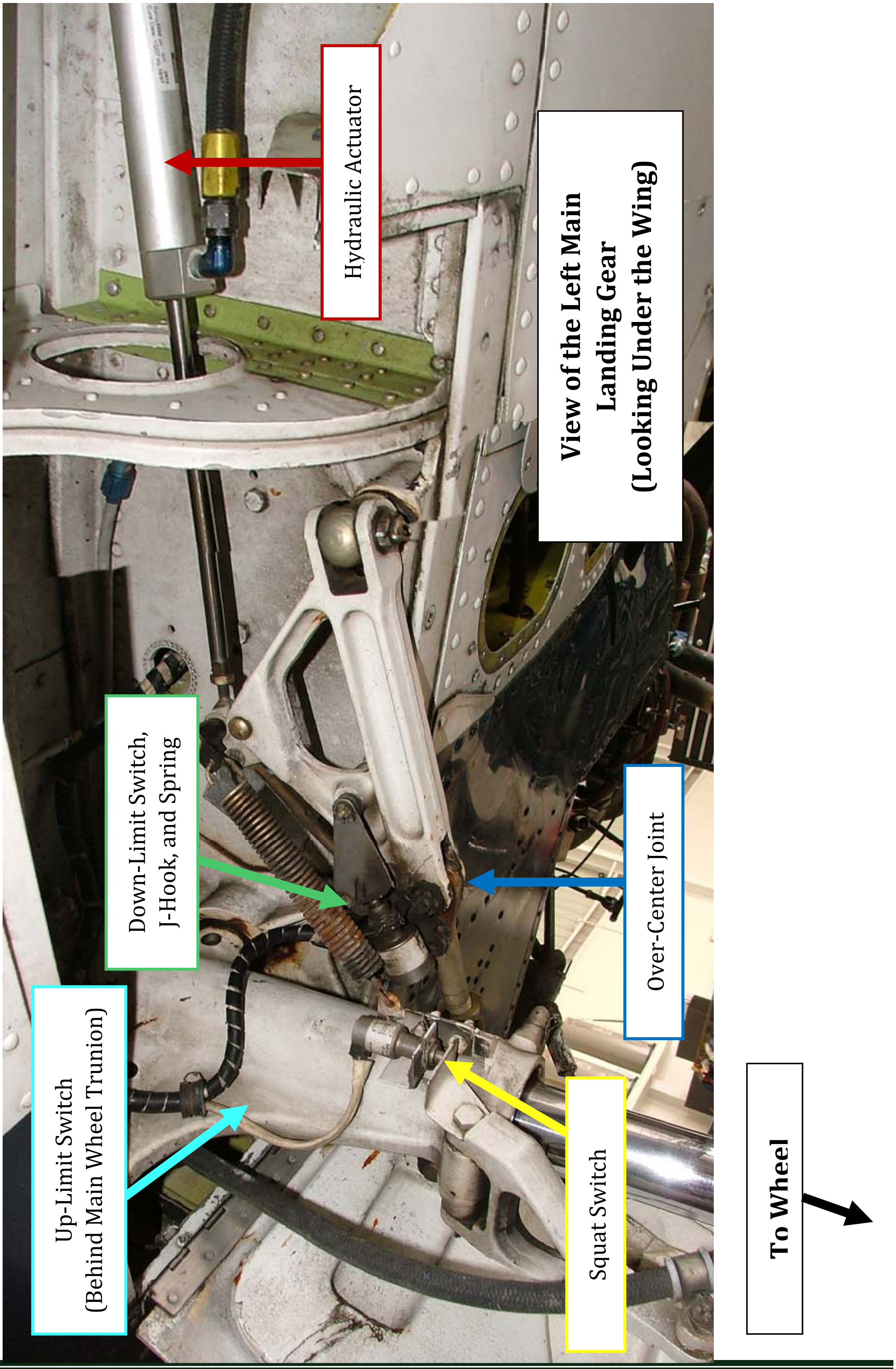
Landing Gear Cockpit Lights and Handle



The three green gear annunciator lights are illuminated when the down-limit switches are depressed. The red WARN GEAR UNSAFE light illuminates when any one of the down-limit switches are not depressed (meaning the gear is not totally down), or up-limit switches are not depressed (meaning the gear is still in transit and not all the way up). All three of the indicator lights are interchangeable to allow troubleshooting possible landing gear extension problems.

If one or two of the gear lights do not illuminate there are three possible reasons:

1. The gear is not locked down.
2. An annunciator light bulb is burned out.
3. There is a malfunction in the indicating system.



View of the Left Main Landing Gear (Looking Under the Wing)

Squat Switch

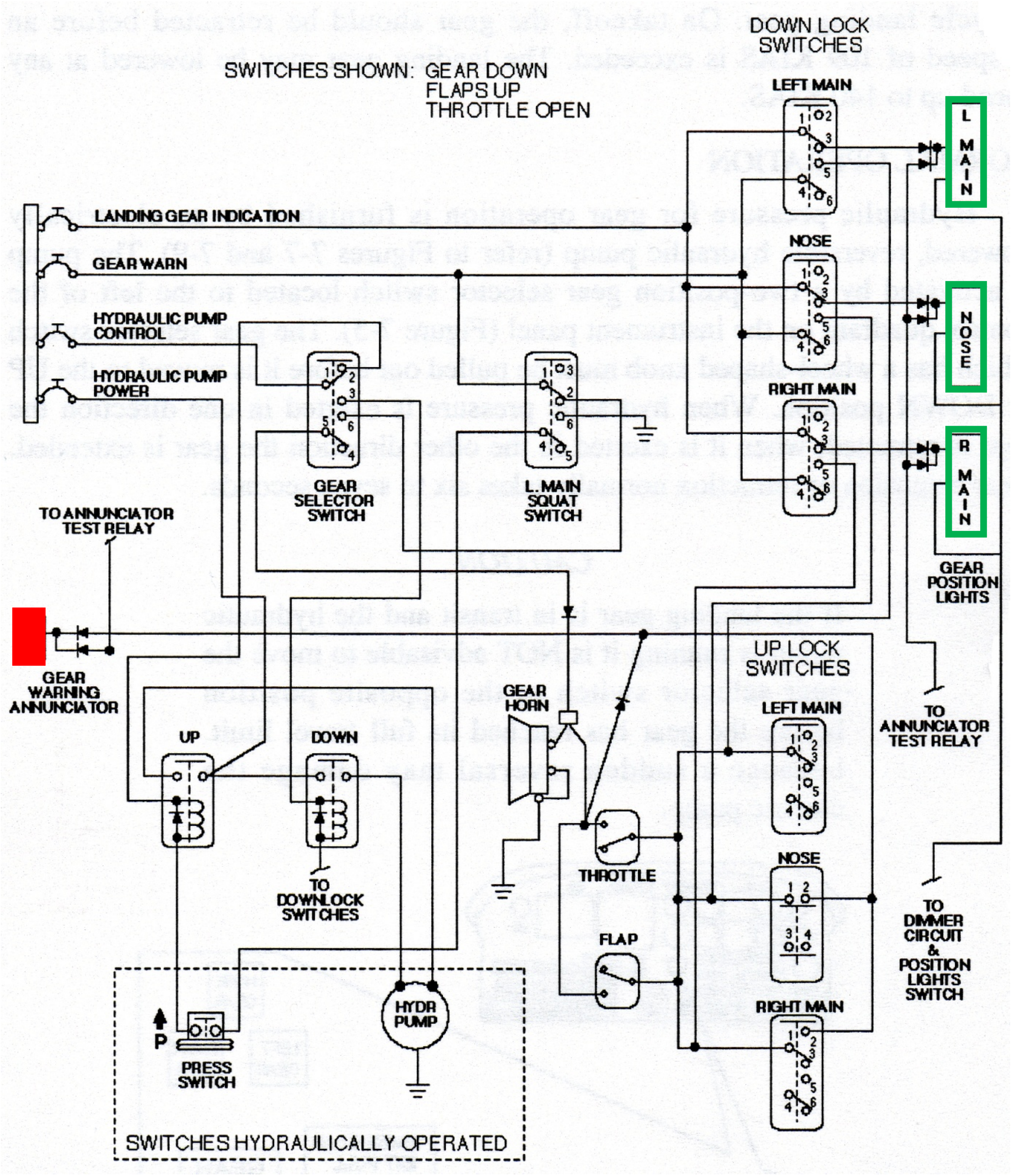
On the Ground

Airborne – Strut extends

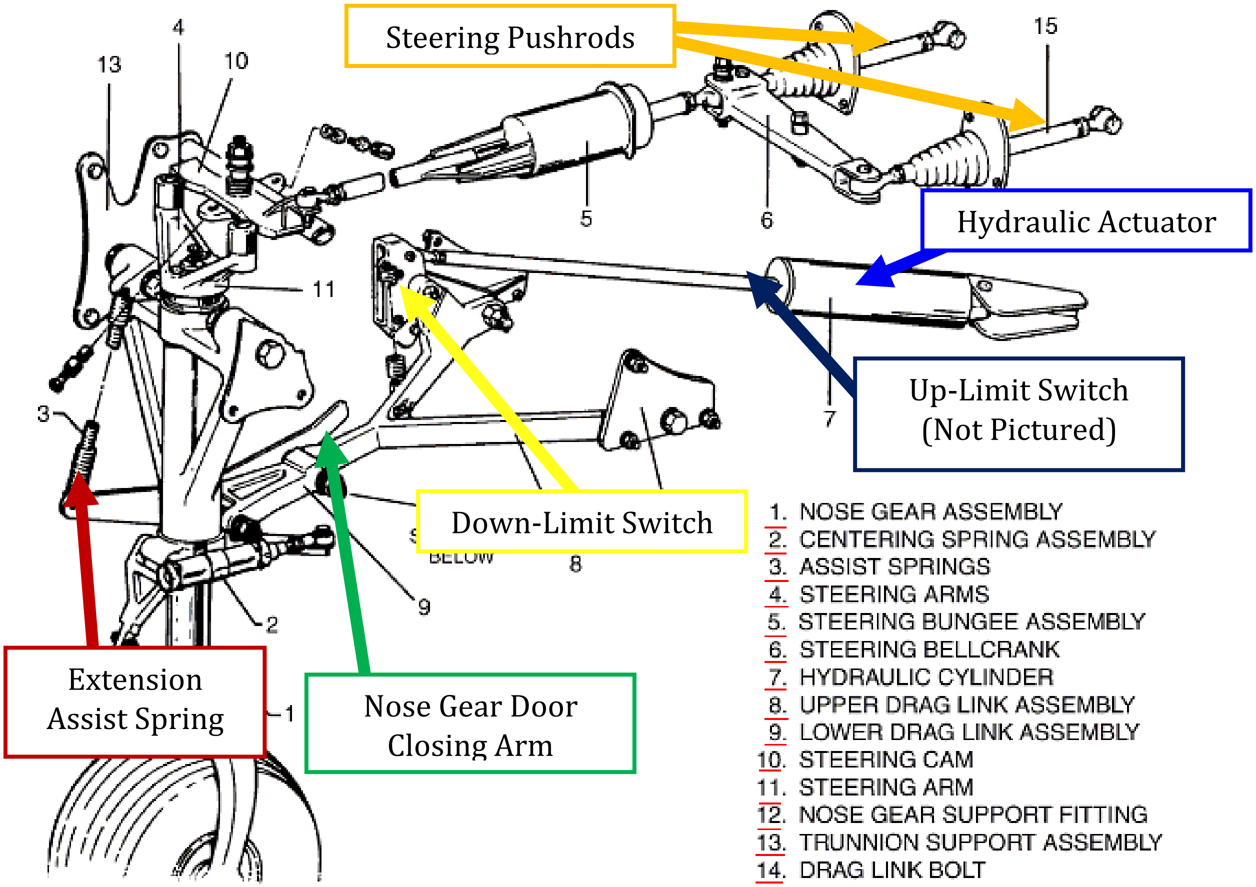
Up-Limit Switch

The main gear up-limit switches (difficult to see) are depressed by the top of the each landing gear trunion (larger metal support that is connected to the oleo strut) as the gear retracts.

Landing Gear Electrical Diagram

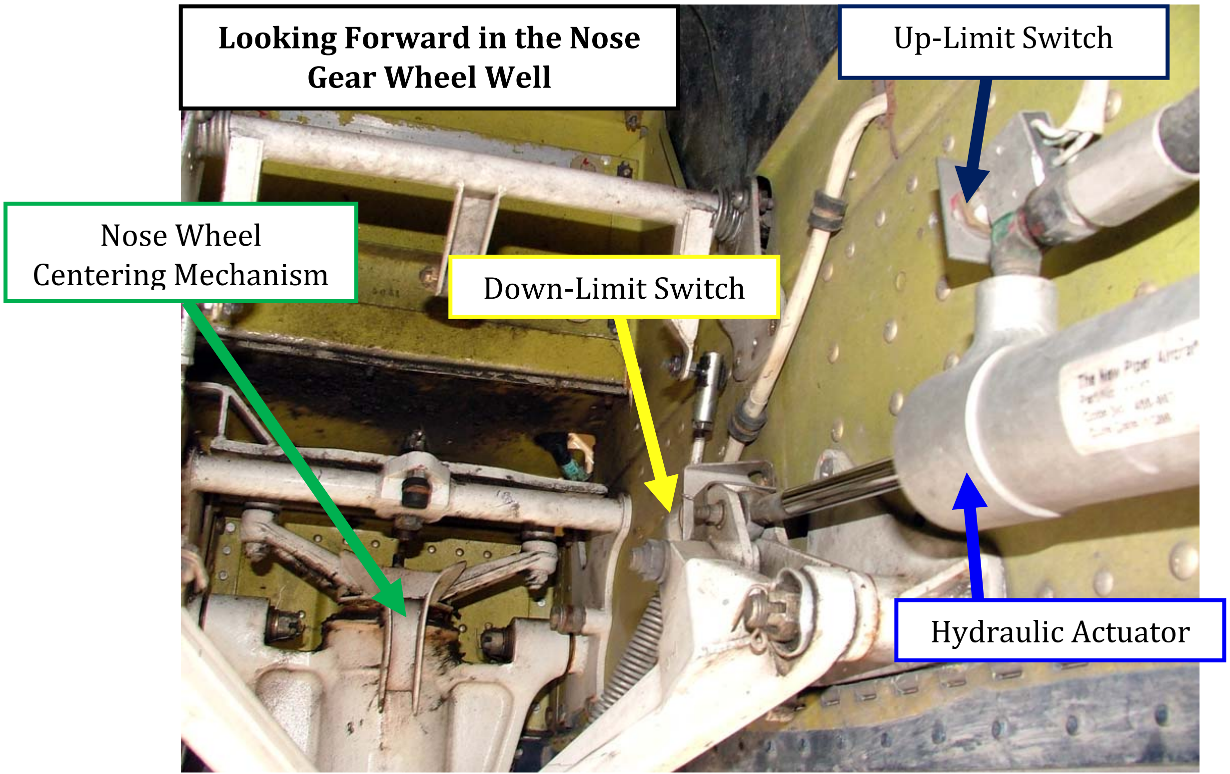


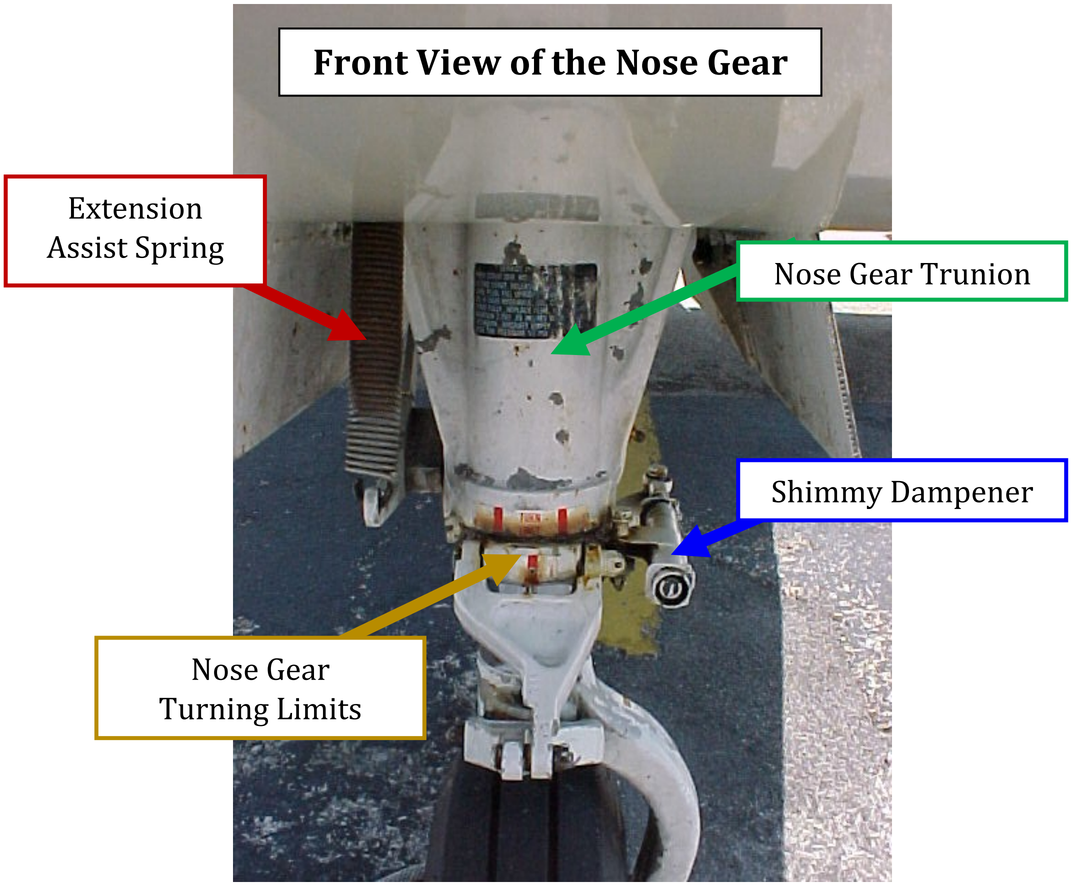
Nose Gear Diagram



1. NOSE GEAR ASSEMBLY
2. CENTERING SPRING ASSEMBLY
3. ASSIST SPRINGS
4. STEERING ARMS
5. STEERING BUNGEE ASSEMBLY
6. STEERING BELLCRANK
7. HYDRAULIC CYLINDER
8. UPPER DRAG LINK ASSEMBLY
9. LOWER DRAG LINK ASSEMBLY
10. STEERING CAM
11. STEERING ARM
12. NOSE GEAR SUPPORT FITTING
13. TRUNNION SUPPORT ASSEMBLY
14. DRAG LINK BOLT
15. STEERING PUSHROD

Looking Forward in the Nose Gear Wheel Well





WHAT HAPPENS WHEN THE GEAR IS RAISED OR LOWERED

To raise the landing gear, the Gear Selector switch must be pulled out slightly and placed (lifted) to the UP position. The gear pump will start and pump fluid into the “retract” side of all three actuators. The down-locks will disengage, the red WARN GEAR UNSAFE light will illuminate, and the landing gear will be retracted (pushed up) by the hydraulic actuators. The hydraulic pump will continue to operate and build-up hydraulic pressure until a pressure switch is activated to shut-off the pump. The red WARN GEAR UNSAFE light will extinguish when all three up-limit switches are depressed. The up-limit switches do not turn the gear pump off. The gear is held in the up position only by hydraulic pressure.

To lower the landing gear, the Gear Selector switch is placed in the Down position. The gear pump will start and pump fluid into the opposite side of the three hydraulic actuators. The landing gear will begin to extend, assisted by gravity and springs. When the up-limit switches are not depressed, the red WARN GEAR UNSAFE light will illuminate. The landing gear pump will continue to operate until all three down-limit switches are depressed. The down-limit switches will also cause the three green landing gear position lights to illuminate. After all three down-limit switches are depressed, the red WARN GEAR UNSAFE light will extinguish.

Never move the Gear Selector switch in the opposite direction (from Up to Down, or Down to Up) while the hydraulic pump is running. **Doing so could damage the gear pump.** Wait until the landing gear has finished its extension or retraction cycle completely and then move the Gear Selector switch to the desired position.

If the NAV lights are On, the landing gear annunciator lights will automatically dim. This may make it difficult to see if all three green lights are illuminated. It is acceptable to briefly turn the NAV lights Off to verify that the three green lights are illuminated to ensure that the landing gear is down-and-locked.

Gear Warning Horn

The Seminole has a landing gear warning horn to help prevent unintentional gear up landings. When activated, the horn beeps at 90 cycles per second and the red WARN GEAR UNSAFE light will illuminate.

The landing gear warning horn will sound in the following three scenarios:

1. Landing gear is not Down-and-Locked and the MP is below 14" on one or both engines.
   This is accomplished by micro-switches positioned on the throttle quadrant near the throttles themselves (not from a MP indication). Because the positioning of the micro-switches are critical to the accuracy of horn actuation, any variation in the location of these switches will cause the gear horn to sound at a MP higher or lower than 14", as appropriate.
2. Flaps are extended to the 2nd or 3rd notch and the landing gear is not down and locked.
3. If the Gear Selector switch is in the UP position when the airplane is on the ground.

The horn can be muted by pushing the yellow GEAR WARN MUTE button. The GEAR WARN MUTE button will illuminate and the horn will cease its 90 cycles per second beeping. The horn can only be muted when it was caused by the position of the throttles. The mute can only be cancelled by moving the throttles or lowering the landing gear.

Emergency Extension

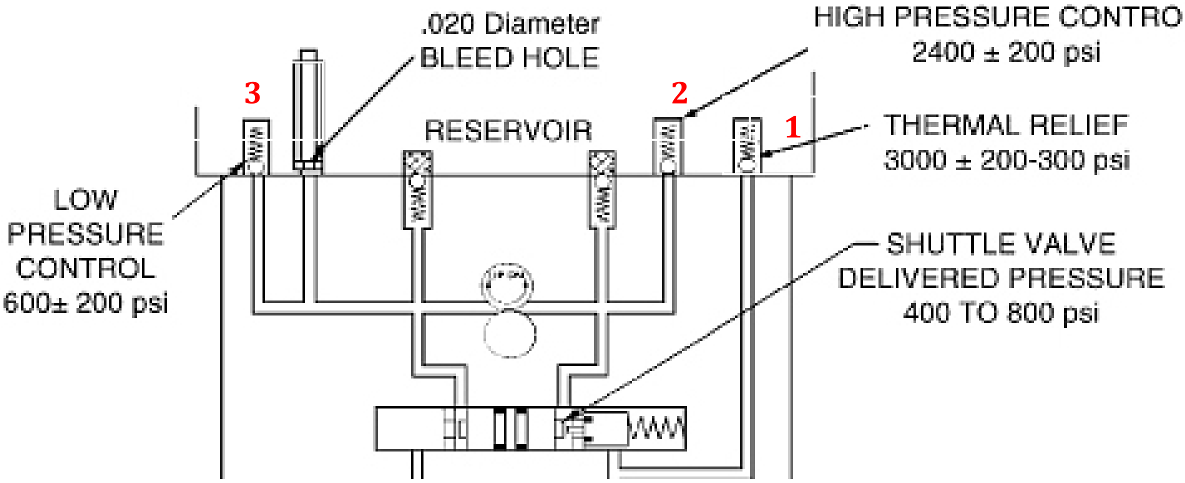
If the landing gear does not extend correctly, there is an emergency extension procedure. Always refer to the proper checklist when conducting this procedure. The emergency extension utilizes a basic pressure relief valve.

The landing gear is held in the UP position by hydraulic pressure. If that pressure is released, gravity will cause the landing gear to free-fall to the Down position. While the landing gear is extending, the piston in the hydraulic actuator will move the hydraulic fluid into the extension side of the gear actuators.

When using the Emergency Gear Extension Knob, move the metal guard up and out of the way of the knob and pull the knob out fully. Leave it out fully. Only Fleet Maintenance personnel should push the knob back in and only after the landing gear system has been checked. The maximum emergency extension speed is 100 KIAS.

Relief and control Valves

The landing gear system has a series of pressure relief and control valves. Again the pressures associated with these valves are not important to memorize.

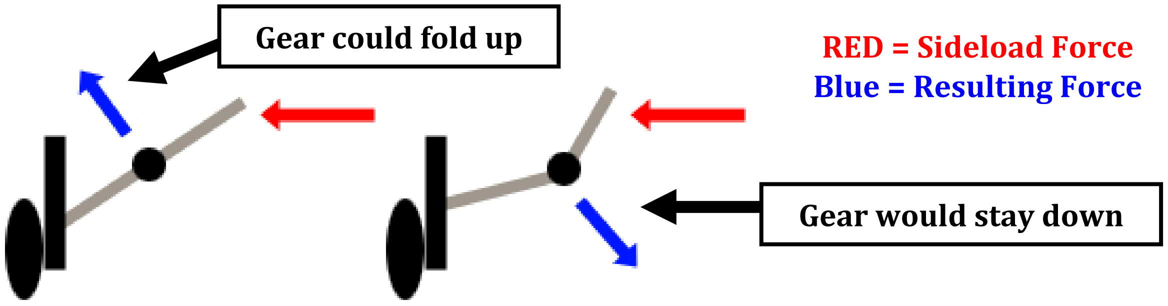


1. **Thermal Relief Valve** – the valve will open to relieve pressure as a result of temperature and pressure changes as the airplane climbs or descends.
2. **High Pressure Control** – if the pressure switch fails to shut off the pump when the landing gear is being retracted, this valve will open to prevent the gear pump from building excessive pressure in the hydraulic system.
    - ➢ **The only way to know if the gear pump is still pumping is to check the alternator amp meters for a higher than normal load. A high load is shown anytime the gear pump is pumping.**
3. **Low Pressure Control** – if the pump fails to shut off when the gear is being lowered, this valve will open up to prevent any damage to the gear pump or system. Again be sure to check the alternator amp gauge to see if the gear pump is running.

If the gear pump will not turn off, the associated circuit breaker can be pulled out to shut off the pump.

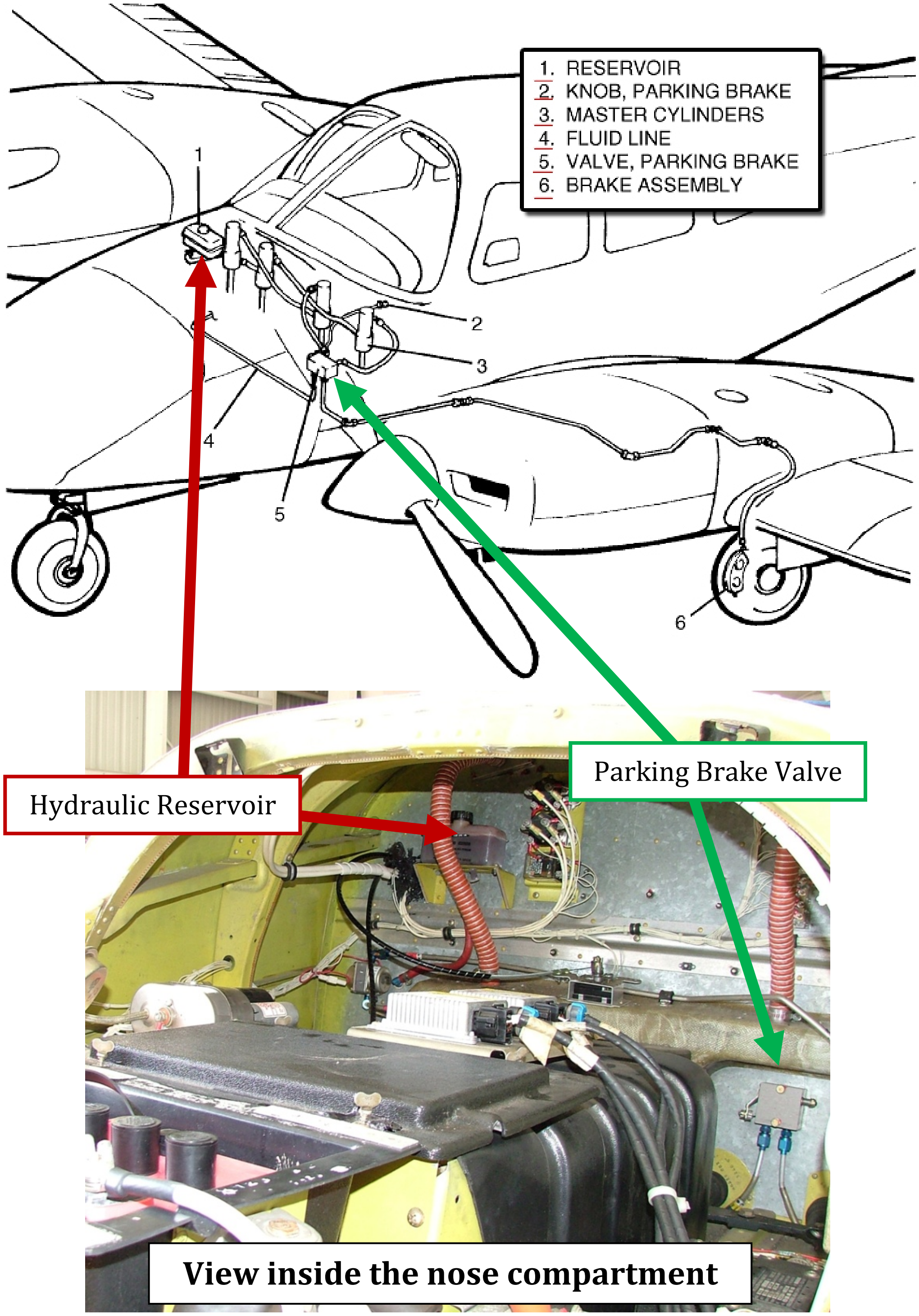
The Over-Center Joint

The over-center joint helps to keep the landing gear fully extended in the event of any side-loading during landing. “Over-center” means that, instead of the joint being in a straight line, it is slightly bent to utilize the force of a side-load to help keep the gear down-and-locked.



BRAKES

The wheel brakes consist of two single-disc, double-puck brake assemblies, one on each main wheel. There are four master brake cylinders, one located behind each rudder pedal. To set the parking brake, depress the brake pedals first and then pull the parking brake handle up. This activates a valve that traps hydraulic pressure in the brake lines. Hydraulic fluid for the brakes and the parking brake valve are located in the nose compartment.



FLIGHT CONTROLS AND TRIM

The empennage consists of a vertical stabilizer and a horizontal tail surface (or stabilator). The stabilator is an all-moveable slab-type with an anti-servo trim tab mounted on the trailing edge. Both the rudder and stabilator incorporate anti-servo trim tabs, which provide longitudinal stability and trim. The ailerons are frise-type with some differential characteristics.

Frise Type Ailerons

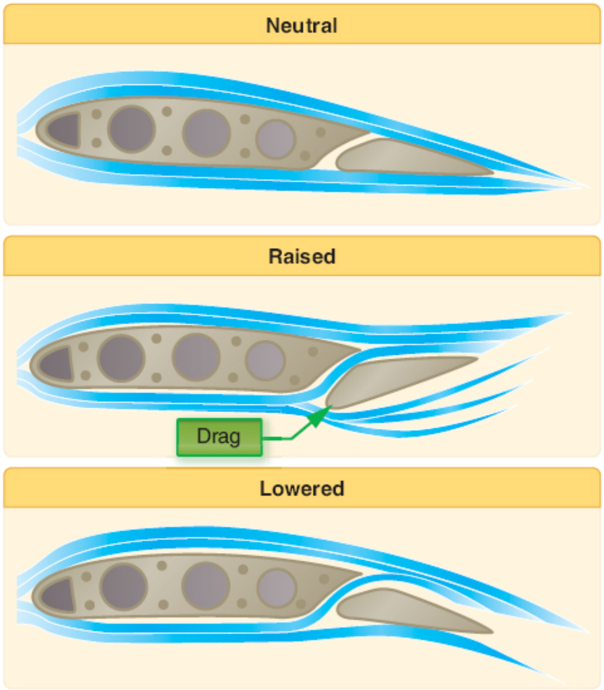
When the yoke is moved the aileron that is being raised pivots on an offset hinge. This projects the leading edge of the aileron into the airflow and creates parasite drag. The drag helps equalize the drag created by the lowered aileron on the opposite wing and reduces adverse yaw. The frise-type aileron also forms a slot so air flows smoothly over the lowered aileron, making it more effective at high angles of attack.

Differential Ailerons

With differential ailerons, the aileron that is raised will travel upward a greater distance than the aileron that is lowered. This produces an increase in drag on the descending wing, the wing with the upward aileron. The greater drag results from the larger deflection of the aileron which results in parasite drag.
In the Piper Seminole the ailerons deflect upward 23° (±2°) and downward 17° (±2°).

The flight controls use a system of gears, chains, cables, pulleys, bellcranks, pushrods, and counterweights.

Frise-Type Ailerons



Differential Ailerons

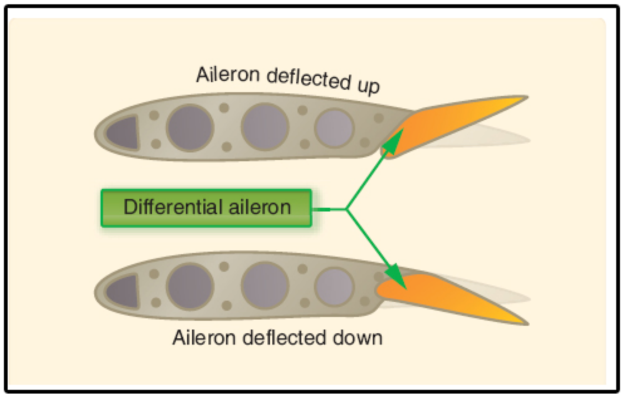
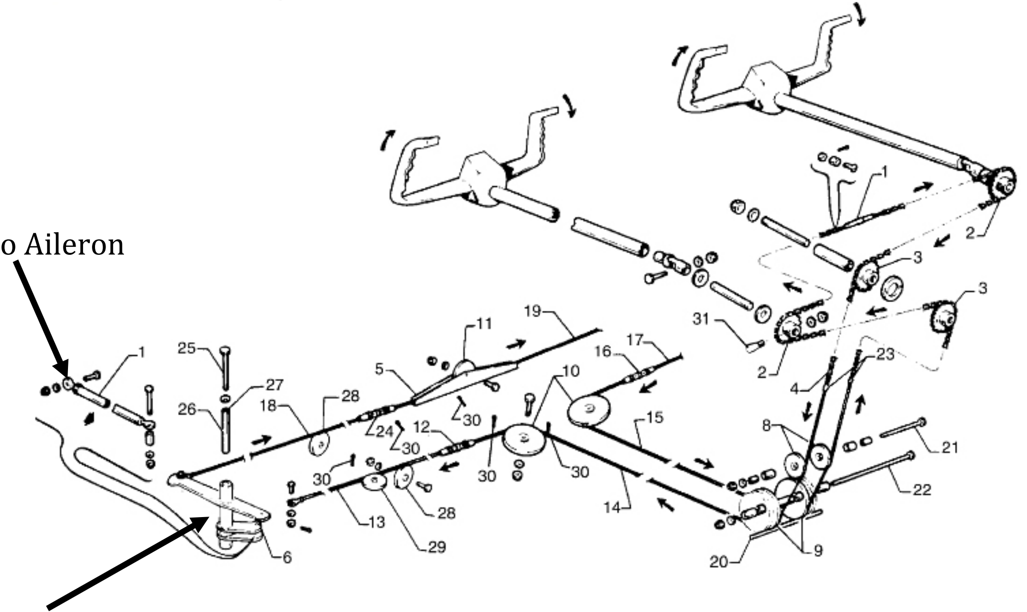


Diagram of the Aileron Controls



Pushrod to Aileron

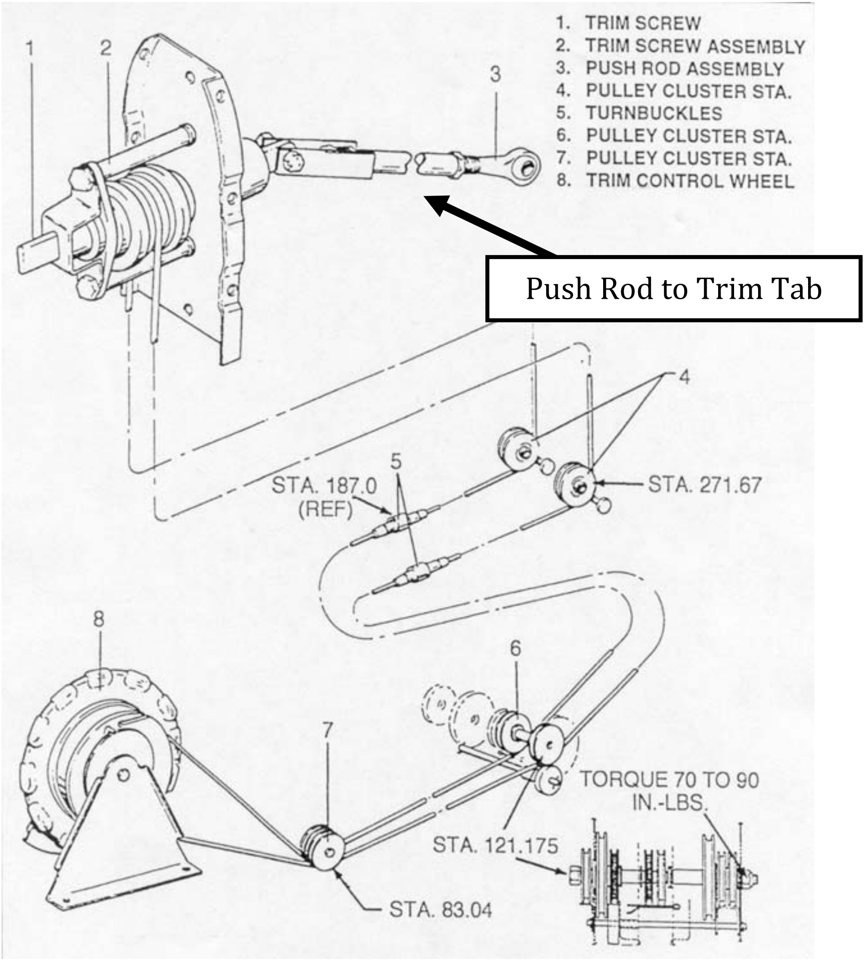
Bellcrank –Takes two cables and changes direction of motion to aileron pushrod.

1. TURNBUCKLE, CONTROL CHAINS
2. SPROCKET CONTROL WHEEL
3. SPROCKET, IDLER
4. CHAIN, AILERON CONTROL
5. BRACKET, PULLEY
6. BELLCRANK, AILERON
7. ROD, AILERON CONTROL
8. PULLEY, TEE BAR
9. PULLEY, FORWARD CLUSTER
10. PULLEY, PRIMARY CONTROL CABLE
11. PULLEY, BALANCE CABLE
12. TURNBUCKLE, RIGHT PRIMARY
13. CABLE, RIGHT WING PRIMARY
14. CABLE, RIGHT FUSELAGE PRIMARY
15. CABLE, LEFT FUSELAGE PRIMARY
16. TURNBUCKLE, LEFT PRIMARY
17. CABLE. LEFT WING PRIMARY
18. CABLE, RIGHT BALANCE
19. CABLE, LEFT BALANCE
20. ROD, CABLE GUARD
21. BOLT, WASHER,& NUT
22. BOLT, WASHER, &NUT
23. BOLT, NUT, BUSHING & COTTER PIN
24. TURNBUCKLE, BALANCE CABLE
25. BOLT, BELLCRANK PIVOT
26. BUSHING, BELLCRANK
27. TUBE, TEFLON
28. PULLEY, LEFT & RIGHT
29. PULLEY - TORQUE TO 25 ± 5 IN. LB.
30. COTTER KEY CABLE GUARDS
31. TAPERED PIN

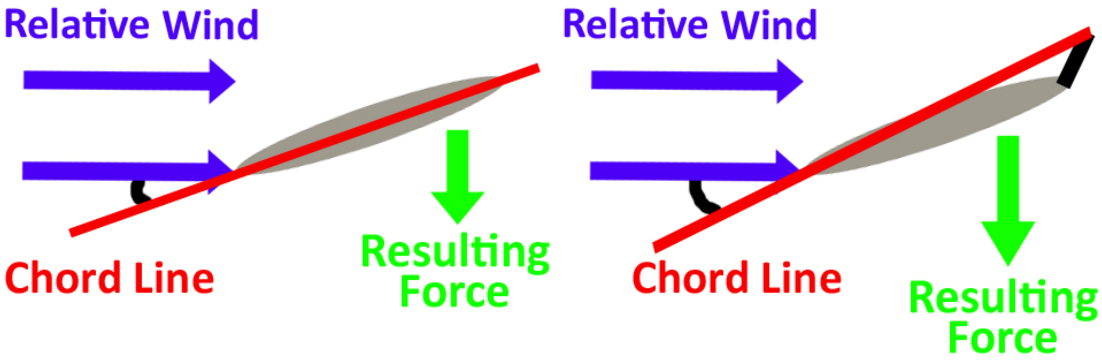
The stabilator and rudder move in a similar manner as the ailerons with gears, chains, cables, pulleys, bellcranks, pushrods, and counterweights.

The stabilator and rudder trim is anti-servo, meaning that the trim tab will move in same direction as the control surface when it is deflected. The trim is controlled by cables, pulleys, pushrods and trim screws that will move the trim tab. Both the rudder and the stabilator trim work in a similar manner.

Elevator Trim Diagram



Anti-Servo Trim Tab



The effects of the anti-servo trim tab will:

1. Increase the angle of attack on the control surface resulting in a more effective control surface.
2. Increase pilot feedback by making it harder for the pilot to move the control surface the more it is deflected up or down.
3. Increase stability by the relative wind forcing the control surface back to the neutral position.

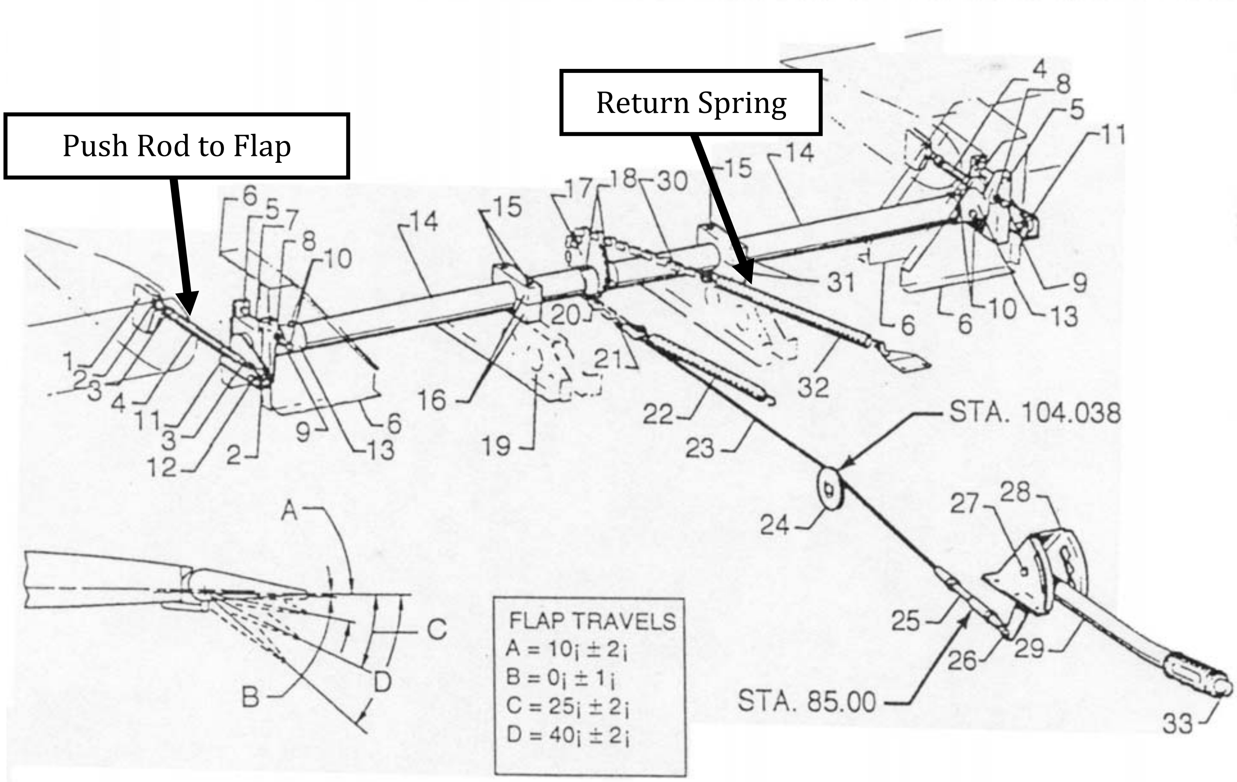
FLAPS

The Seminole incorporates plain flaps that are extended and retracted by a manual flap control handle. The flaps are extended by a control cable and pushrods with the use of the flap control handle. The flaps can be selected in 4 different positions: 0, 10, 25, and 40 degrees.

The flaps are spring-loaded to return to the retracted (0°) position. The flap control handle incorporates a button that must be pressed only when retracting the flaps. The button does not need to be depressed to extend the flaps. The right flap incorporates a lock to allow the right flap to be used as a step.

The maximum flaps operating speed is 111 KIAS.

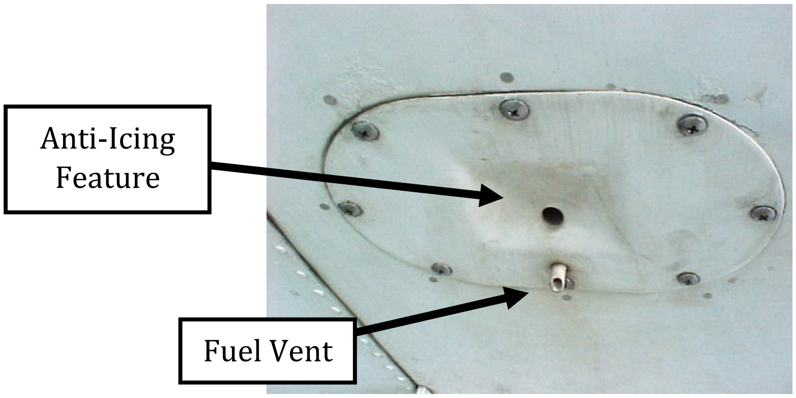
Flap Diagram



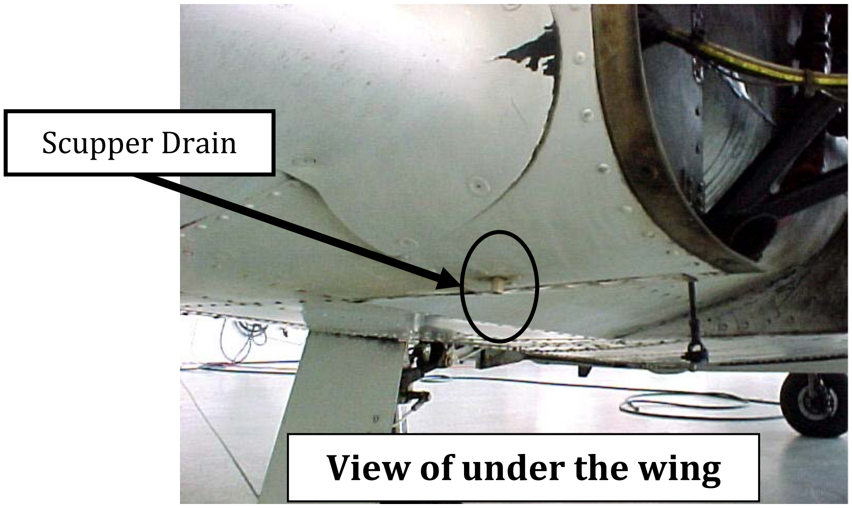
1. BRACKET, ROD ATTACHMENT
2. BOLT, WASHER & NUT
3. JAM NUT
4. ROD, FLAP CONTROL
5. BOLT, BEARING BLOCK ATTACHMENT
6. BRACKET, BEARING BLOCK
7. BLOCK, BEARING
8. NUT, LOCK
9. SCREW, FLAP ADJUSTMENT
10. BOLT, WASHER & NUT
11. CRANK (ARM), TORQUE TUBE
12. BOLT, WASHER & BUSHING
13. FITTING, TORQUE TUBE STOP
14. TUBE, TORQUE
15. BOLT, WASHER & NUT
16. BLOCK, BEARING
17. SPROCKET. TENSION SPRING
18. BOLT, WASHER & NUT
19. BRACKET, BEARING BLOCK
20. CHAIN, TENSION SPRING
21. CLEVIS BOLT, BUSHING NUT & COTTER PIN
22. SPRING, TENSION
23. CABLE, FLAP CONTROL
24. PULLEY
25. TURNBUCKLE
26. CLEVIS BOLT, NUT & COTTER PIN
27. BOLT, BUSHING, WASHER & NUT
28. BRACKET, FLAP HANDLE
29. FLAP HANDLE
30. CHAIN, RETURN SPRING
31. BLACK, BEARING
32. SPRING, RETURN
33. BUTTON, FLAP RELEASE

FUEL

There are two 55 gallon total fuel cells (54 usable), one in each nacelle (behind each engine). The total capacity is 110 gallons with 108 gallons of fuel usable. The fuel tanks are made of a rubber bladder. There are four fuel vents, one in each fuel cap and one under each wing. The vents under the wing feature an anti-icing design. The curvature in front of the fuel vent disturbs the air and prevents ice from forming on the exposed fuel vent.



If fuel is spilled by the fuel cap, or if the tank is over filled, a drain called a scupper drain removes the excess fuel. The Scupper Drain is located underneath the engine on each wing.



Two fuel drains are located on the right side of the fuselage near the baggage door.

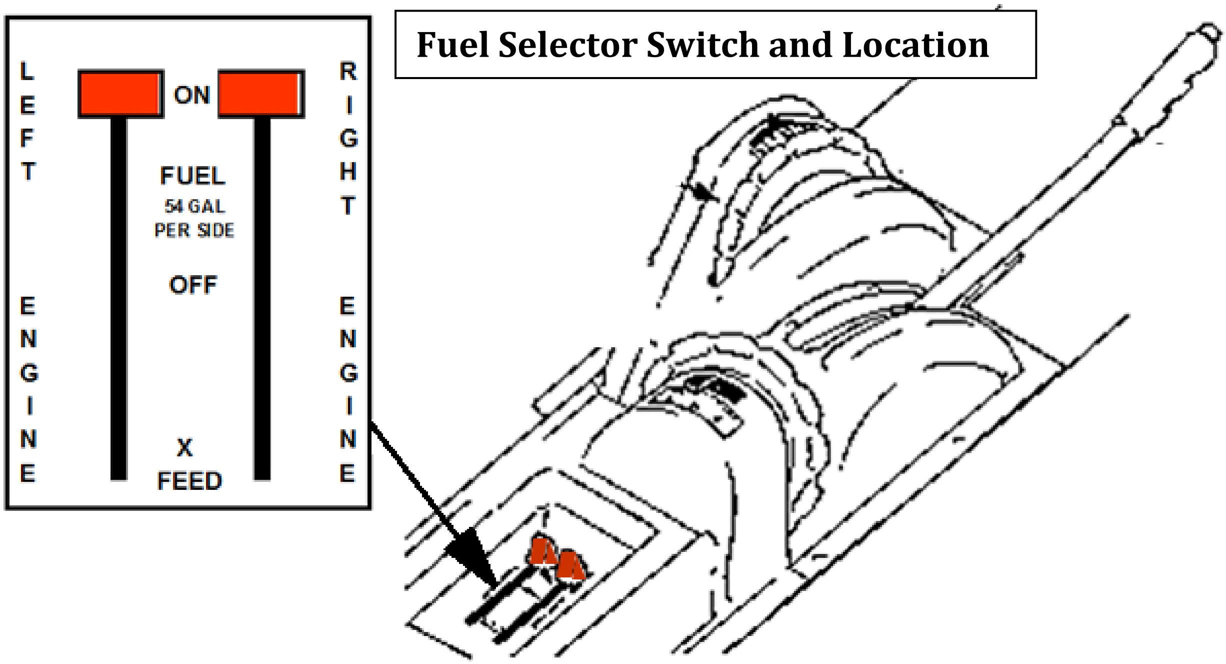
The system also contains two engine-driven fuel pumps and two electrical fuel pumps. The electric fuel pumps are a backup in case the engine driven pumps fail and are also used when priming the engine. When priming the engine only three of the cylinders are primed; the fourth cylinder, where manifold pressure is measured, is not primed. The electric fuel pumps must be on to prime the engine.

The manifold pressure gauge measures the absolute pressure of the fuel/air mixture inside the intake manifold and is more correctly a measure of manifold absolute pressure (MAP). (The intake manifold is the pipe that carries the fuel air mixture to the cylinder from the carburetor). At a constant rpm and altitude, the amount of power produced is directly related to the fuel/air flow being delivered to the combustion chamber. As the throttle setting is increased, more fuel and air flows to the engine and MAP increases. When the engine is not running, the manifold pressure gauge indicates ambient air pressure (i.e., 29.92 inches of mercury).

Manifold Pressure Gauge

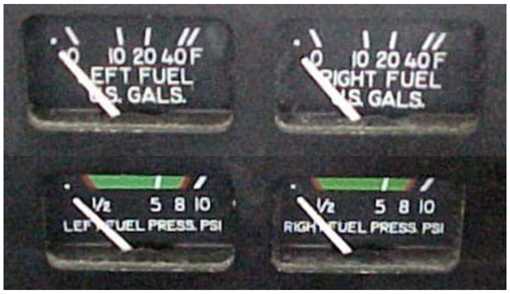
There is a fuel selector for each engine that has a 3-position switch (ON, OFF, X-Feed (crossfeed). If the left engine fuel selector is ON, fuel will be used from the left tank to the left engine. If the left engine fuel selector is OFF, no fuel will flow to the left engine. If the left engine fuel selector is in the X-Feed position, fuel will be fed from the right fuel tank to the left engine. The right fuel selector works in a similar way, but with the opposite tank.

Fuel Selector Switch and Location

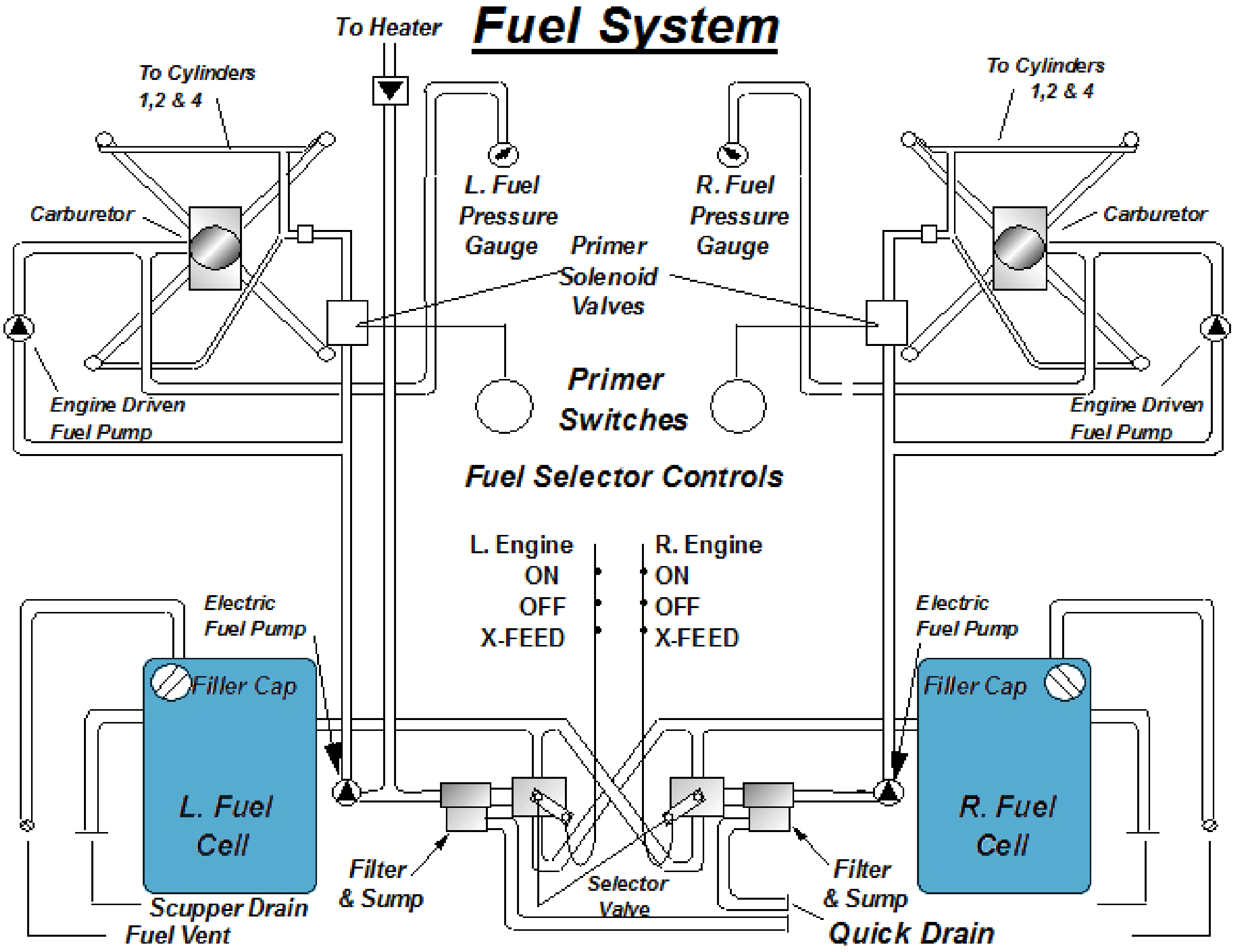


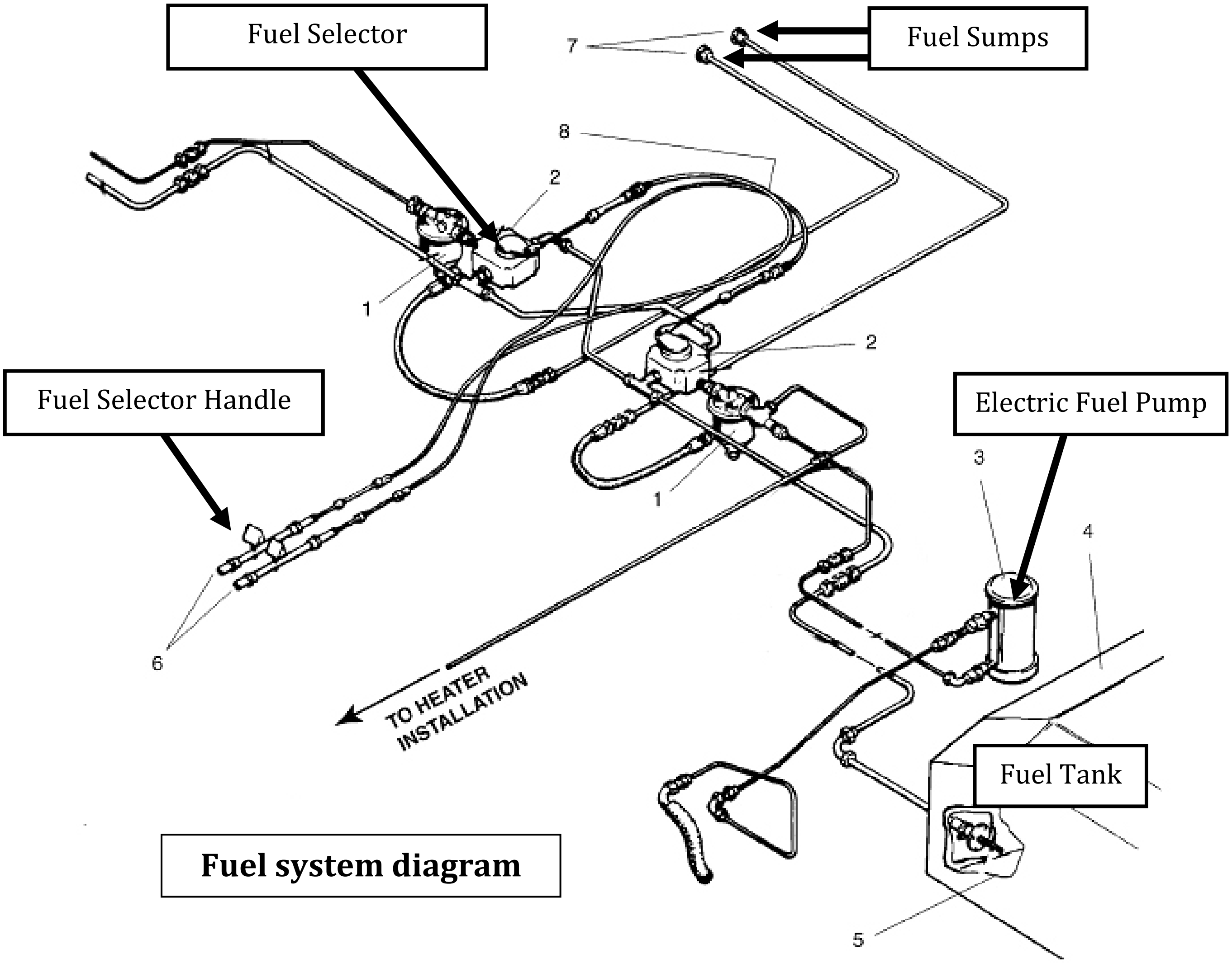
The crossfeed position should only be used in level flight and then only to keep the fuel load balanced across the airplane (usually in a single engine scenario). In flight, the fuel selectors should never both be in the X-Feed position. Do not takeoff or land with a fuel selector in the X-Feed position.

There are two fuel quantity gauges as well as two fuel pressure gauges located on the instrument panel in front of the pilot.

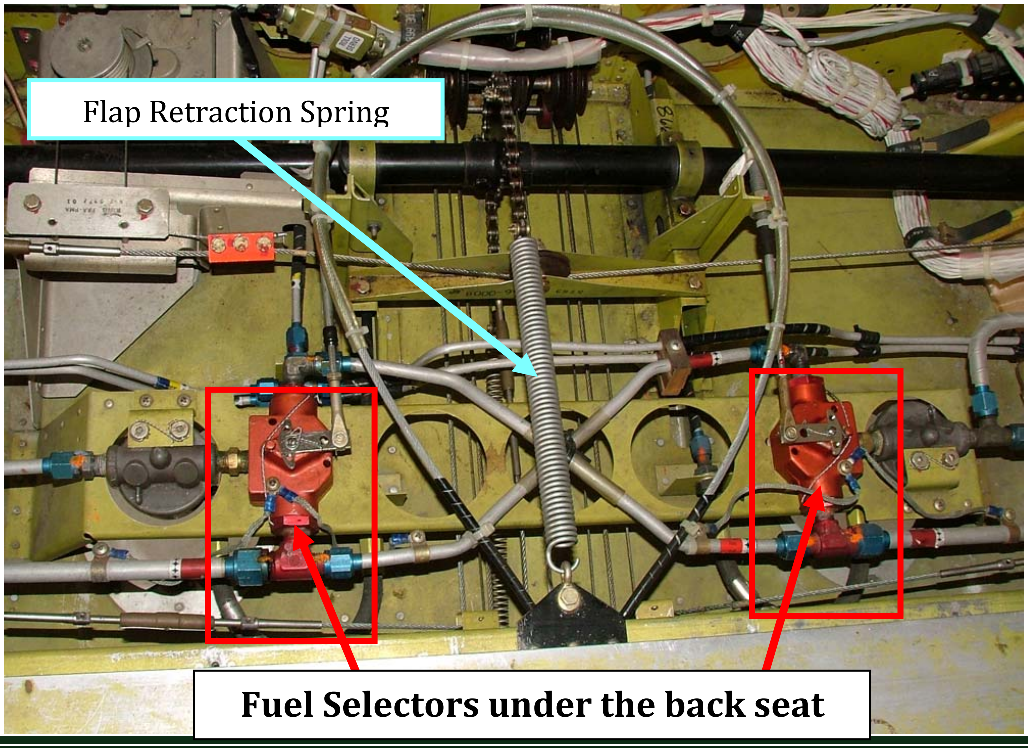


When turning off the fuel pumps in flight, only turn them off one at a time, checking the fuel pressure after turning each pump off. Doing so will help prevent the possibility of fuel starvation to an engine and/or notice the failure of an engine driven fuel pump.

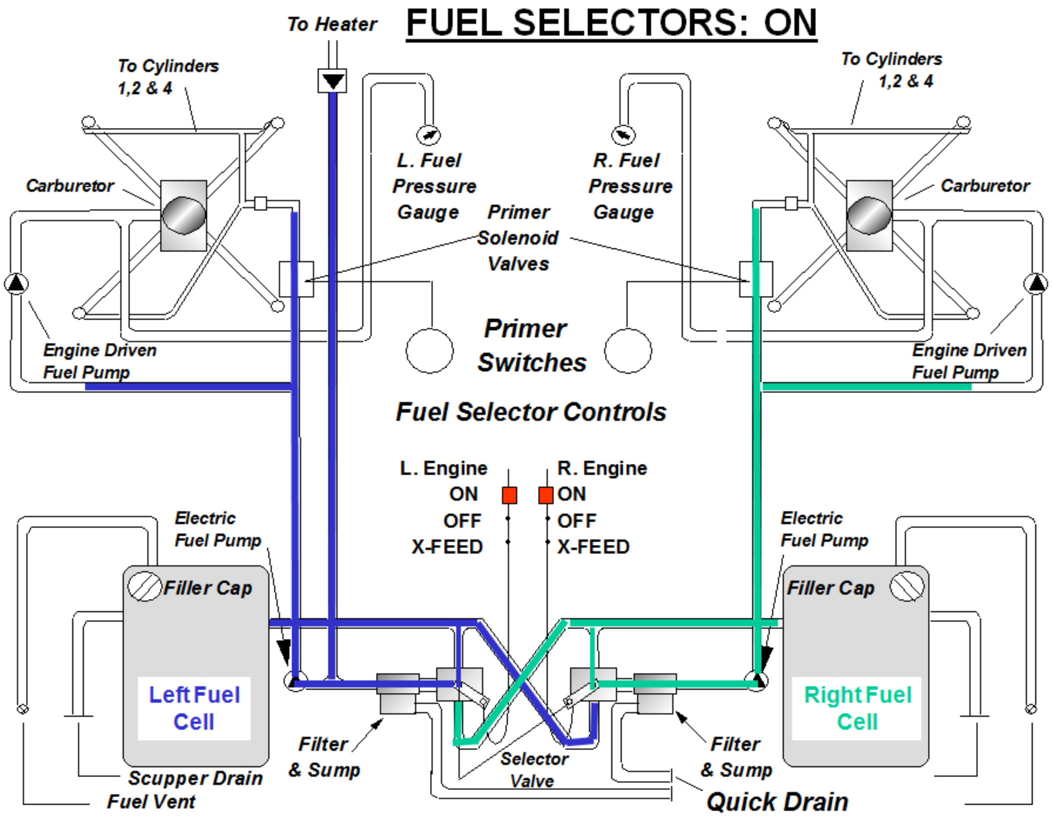


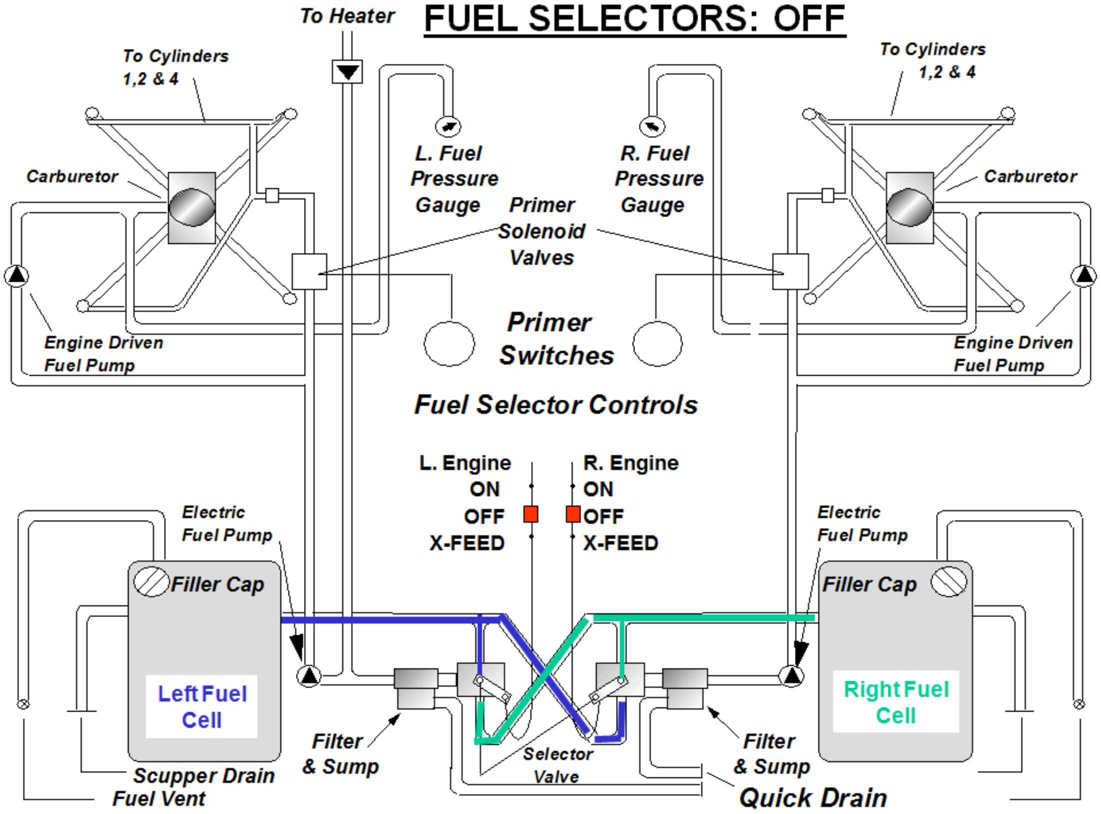


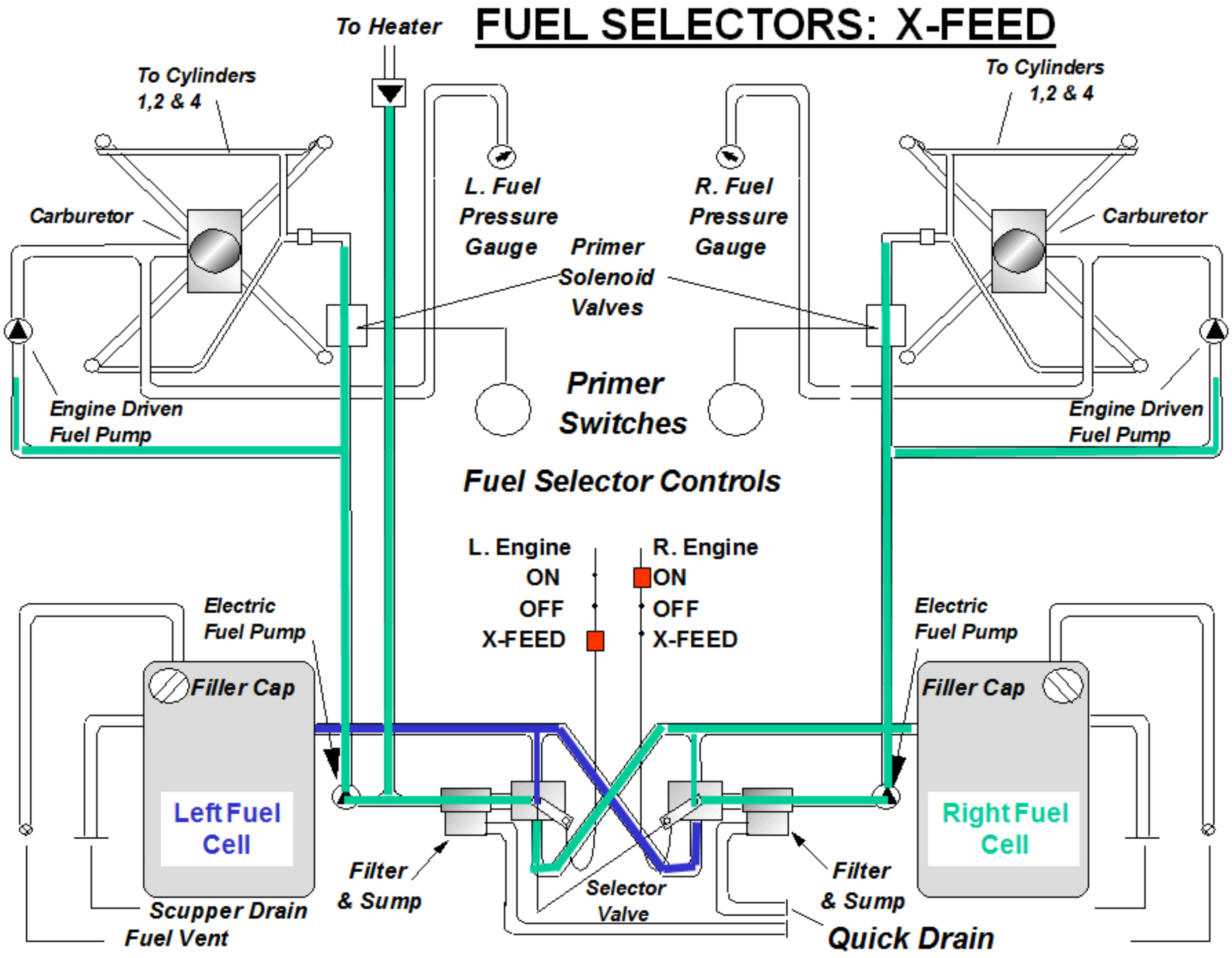
Fuel system diagram



Fuel Flow Examples




FUEL SELECTORS: OFF
To Heater
To Cylinders 1,2 & 4
To Cylinders 1,2 & 4
Carburetor
Carburetor
L. Fuel Pressure Gauge
R. Fuel Pressure Gauge
Primer Solenoid Valves
Primer Switches
Engine Driven Fuel Pump
Engine Driven Fuel Pump
Fuel Selector Controls
L. Engine
ON
OFF
X-FEED
R. Engine
ON
OFF
X-FEED
Electric Fuel Pump
Electric Fuel Pump
Filler Cap
Filler Cap
Left Fuel Cell
Right Fuel Cell
Filter & Sump
Filter & Sump
Selector Valve
Scupper Drain
Fuel Vent
Quick Drain


To Heater
FUEL SELECTORS: X-FEED
To Cylinders 1,2 & 4
To Cylinders 1,2 & 4
Carburetor
Carburetor
L. Fuel Pressure Gauge
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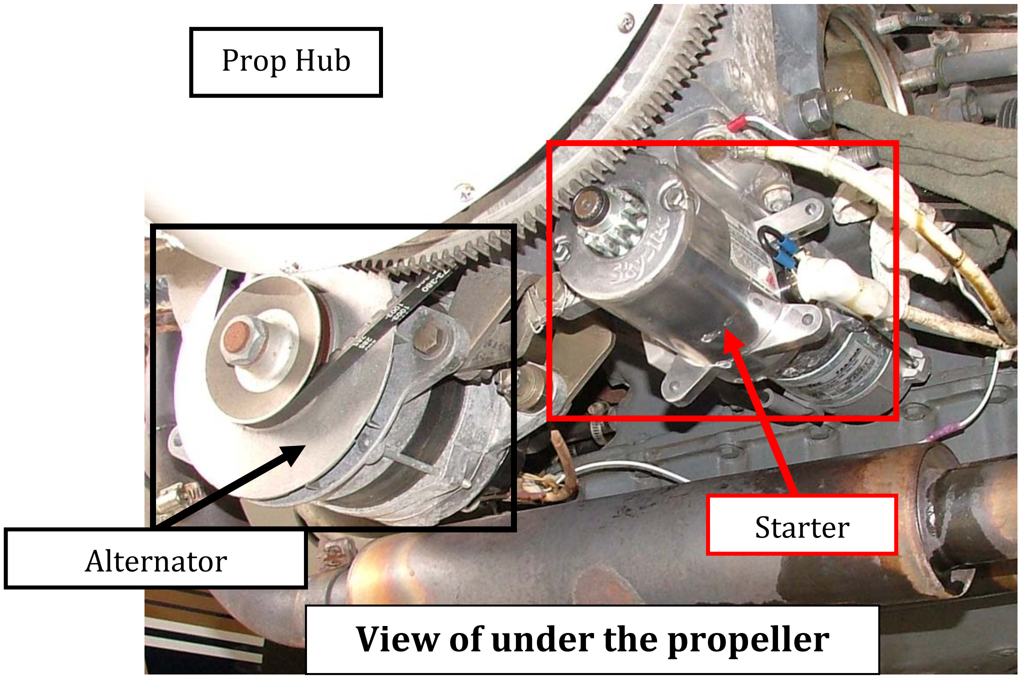
Electric Fuel Pump
Electric Fuel Pump
Filler Cap
Filler Cap
Left Fuel Cell
Right Fuel Cell
Filter & Sump
Filter & Sump
Selector Valve
Scupper Drain
Fuel Vent
Quick Drain

ELECTRICAL

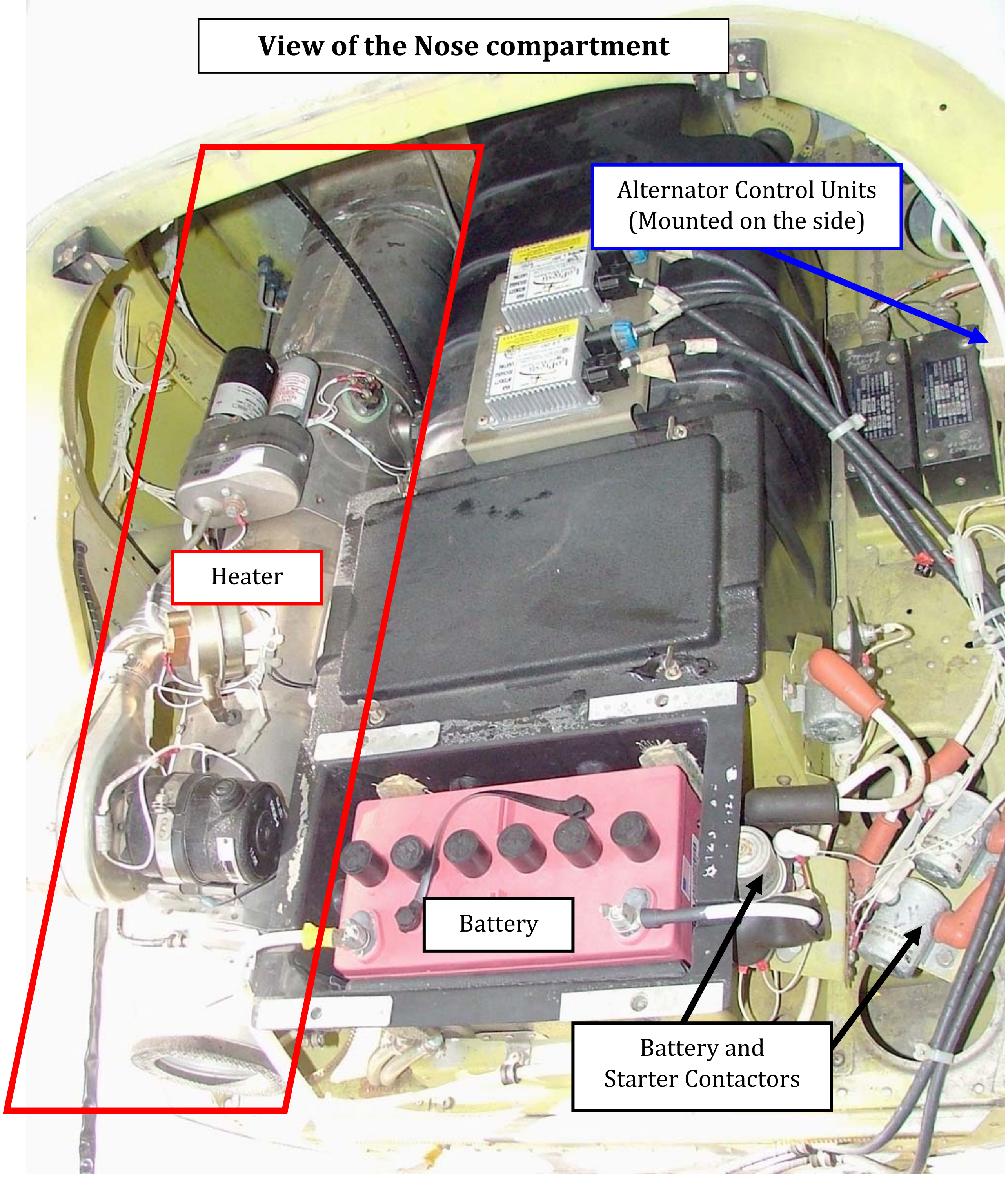
The electrical system is a negative-ground, dual-fed, spilt-bus system. There are two belt-driven, 14-volt, 70 ampere alternators; one mounted on each engine.

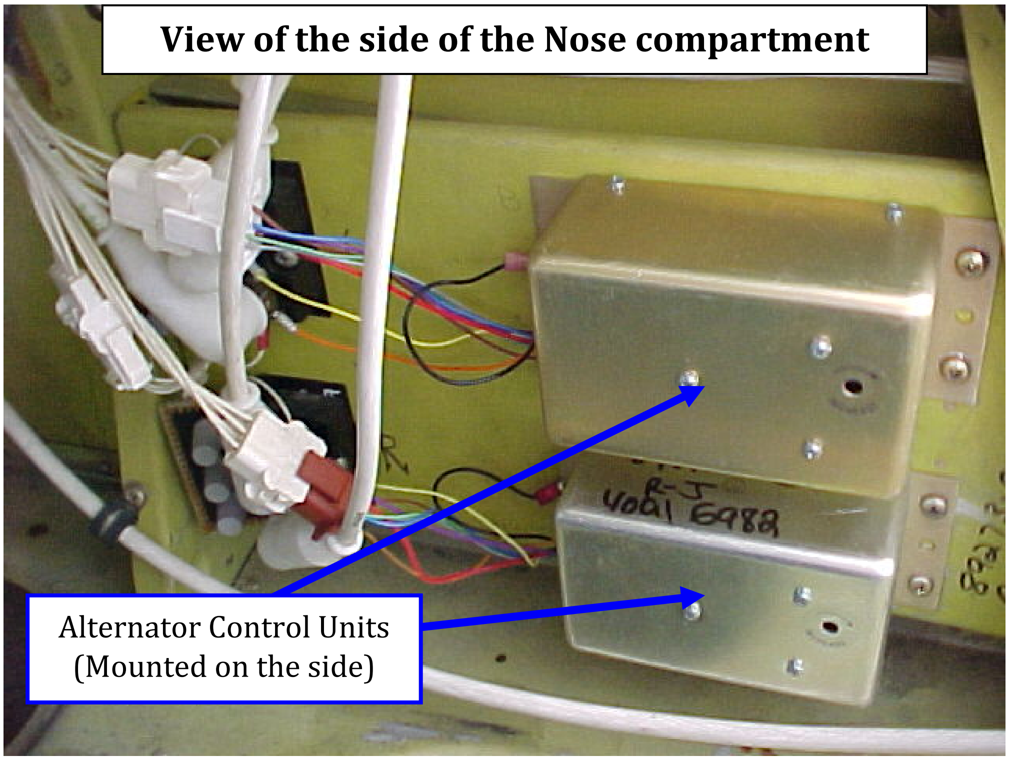


Each alternator has an alternator control unit, located in the nose compartment, which uses a voltage regulator and an overvoltage relay. The regulators maintain 14 volts in the system between the two alternators (load sharing). They will also recognize if one alternator fails and still maintain a constant 14 volts in the system. The overvoltage relay will take the alternator offline if the voltage exceeds 17 volts.

The battery (12 volt, 35-ampere hour) is located in the nose compartment and is kept charged by the 14 volt alternators. The battery and alternator switches incorporate a relay or contactor. A relay or contactor can be thought of as a remote switch. For example the battery master switch activates the battery contactor which then connects the battery to the system. This accomplishes two things: 1. It keeps the larger amounts of electrical energy away from the pilot. 2. It keeps the amount of heavier gauged wire down to a minimum, reducing electrical resistance and overall weight.

There are circuit-breakers to protect the electrical system and equipment. A circuit-breaker contains a piece of metal that will heat and expand when electricity moves through it. If the circuit breaker has more than the normal amount of electricity flowing through it, the metal will get very hot, expand a great deal, and actually push out or “pop” the circuit breaker. Re-setting, the circuit-breaker requires a “cool down” period of a few minutes (Piper recommends 2 to 5 minutes) to allow the metal and other electrical wires to cool down. Repeated re-setting of the circuit-breaker after it pops out could result in a fire. Some circuit-breakers are designed to be pulled out manually.


View of the Nose compartment
Alternator Control Units
(Mounted on the side)
Heater
Battery
Battery and
Starter Contactors

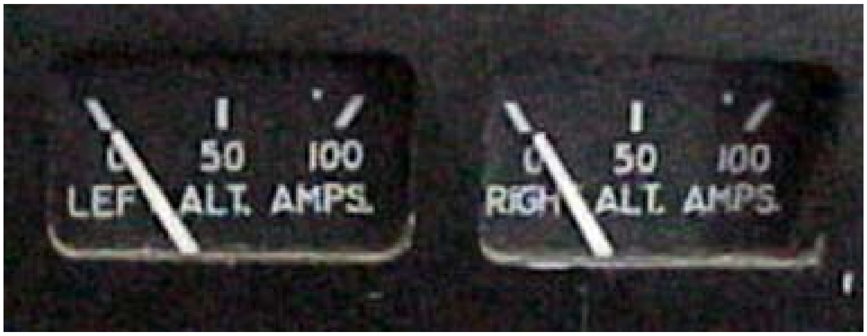


The electrical systems contain 6 bus bars which distribute the electricity. The names of the busses can be remembered by using the acronym BATMAN.

1. Battery Bus
2. Avionics Bus #1
3. Tie Bus
4. Main Bus
5. Avionics Bus #2
6. Non-Essential Bus

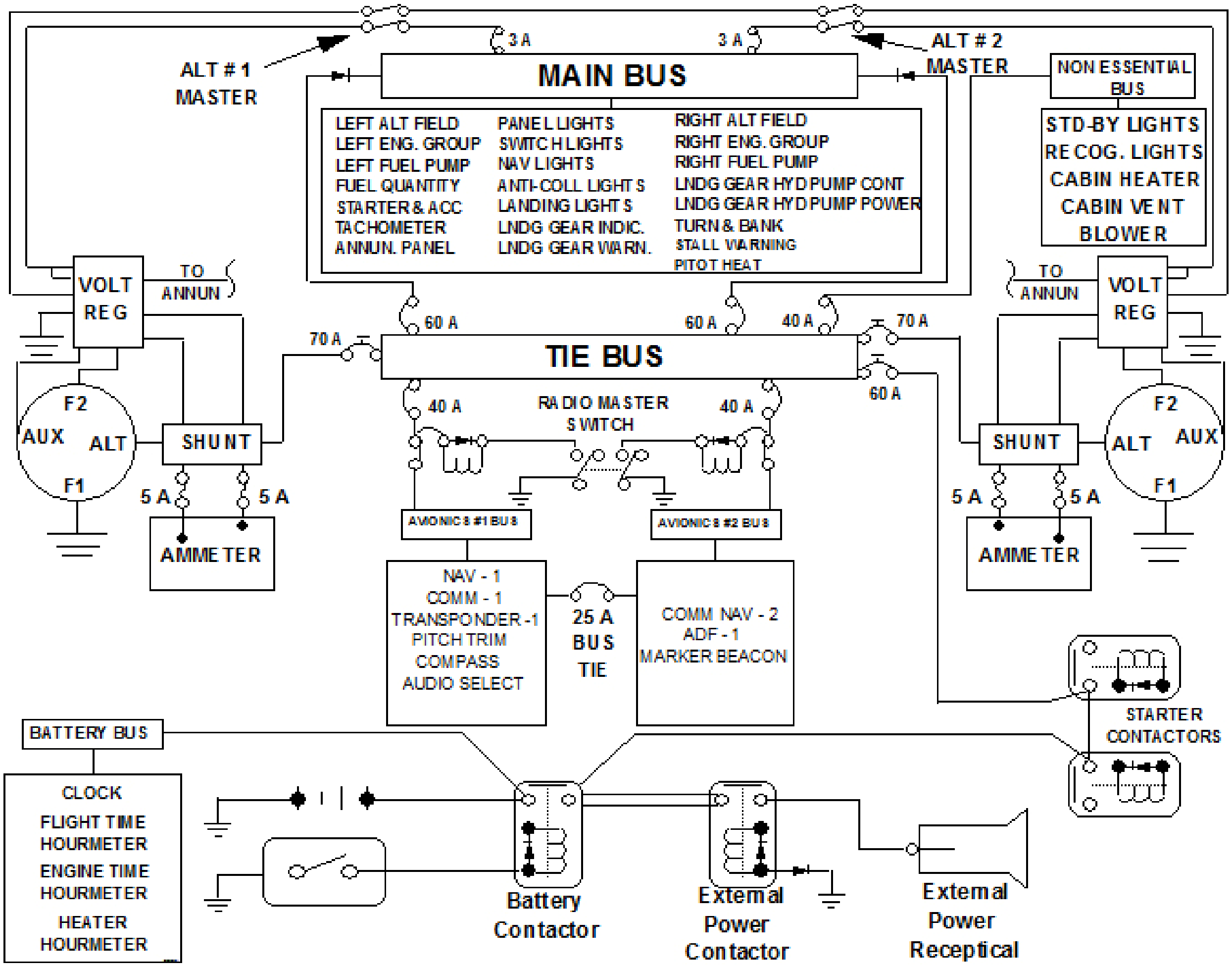
The non-essential bus is a bus that can be deactivated to quickly help reduce electrical load in the case of a single or dual alternator failure.

To monitor electrical loads and the system there are two ammeters which measure the individual electrical load of each alternator.



External power of 14 volts may be used to power the airplane. It would be plugged in underneath the nose and to the right of the nose wheel doors. It is a good practice to start one engine with external power, then disconnect the external power and start the other engine on the airplanes own power system to help make sure it is working properly. Be sure to refer to the appropriate checklist before doing this procedure.

Electrical System Diagram



VACUUM SYSTEM

The vacuum systems uses two engine-driven, dry-type vacuum pumps (dry-type means no liquid lubrication is used inside the pump). These pumps are connected to the accessory case on the back of each engine and contain a shear drive. If the vacuum pump would break or seize up and not spin freely the shear drive will "shear" off and disconnect the pump from the engine's accessory case to prevent damage to the engine.

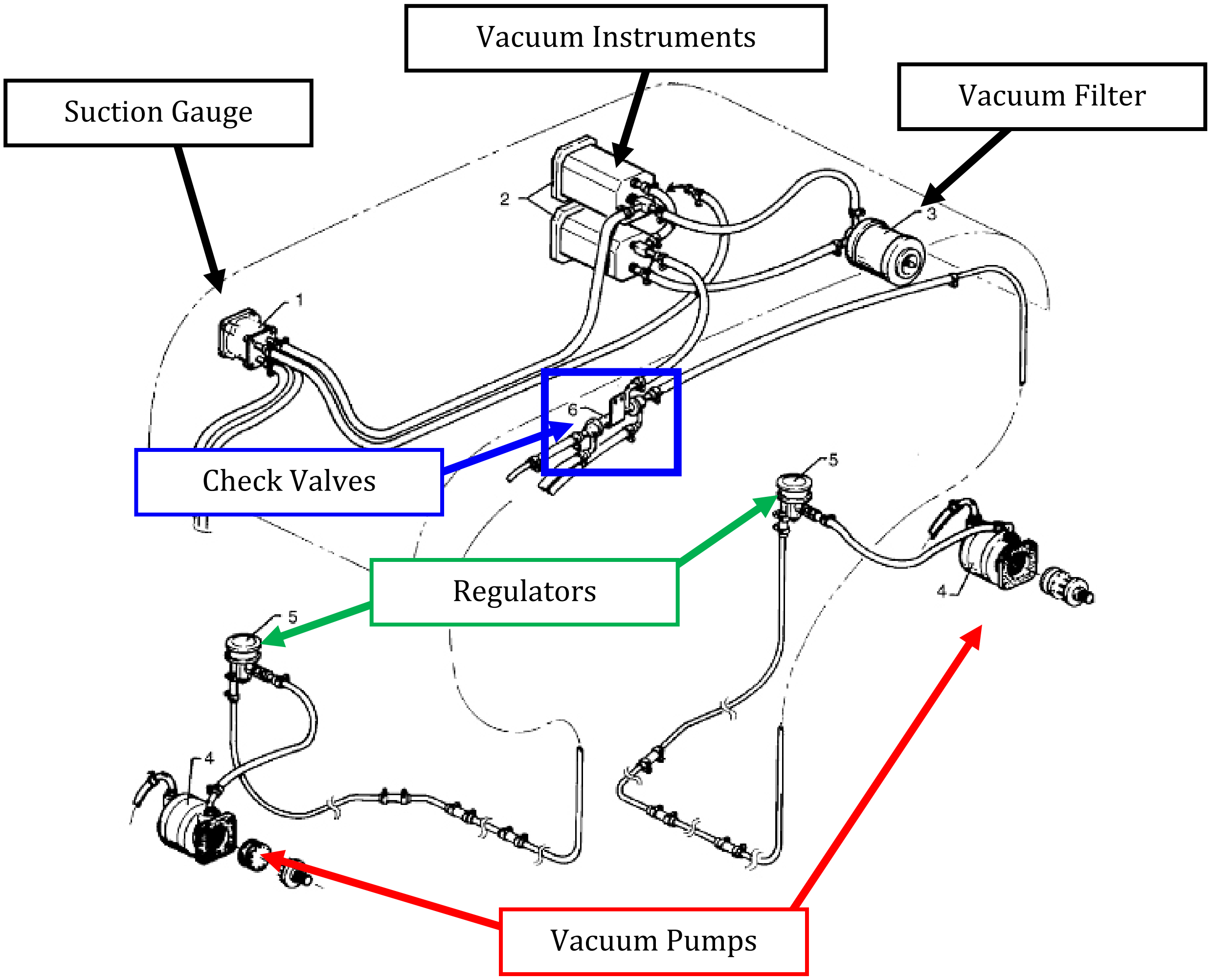
Vacuum Filter

Vacuum Pump

The vacuum filter is located under the instrument panel and allows filtered air from inside the cabin to flow into the vacuum system.

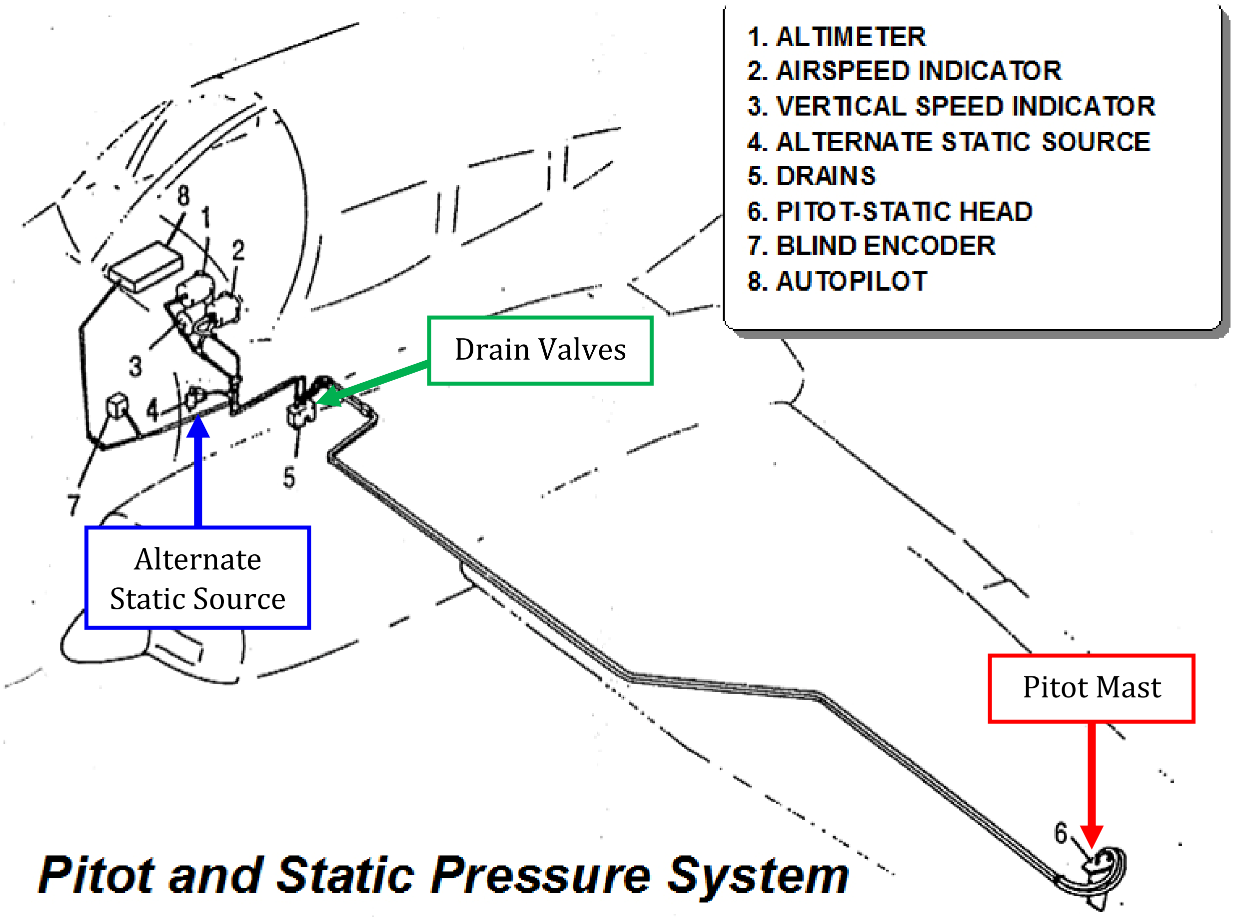
Normal suction is 4.8 to 5.2 inches of mercury. There is a regulator near each pump to prevent excessive suction in the system. There is also a set of check valves that can, in the event of a pump failure, separate that pump from the system to maintain proper vacuum suction in the system. The suction gauge has red flow buttons which allow the pilot to see if anyone of the pumps has failed. A red button will "pop out" in the event of a vacuum pump failure.

Vacuum System Diagram



PITOT STATIC

The pitot static system supplies pitot and static pressure to the airspeed indicator and static pressure to the altimeter, vertical speed indictor, and blind encoder. (The blind encoder is what sends the altitude of the airplane to ATC.)



Pitot and Static Pressure System

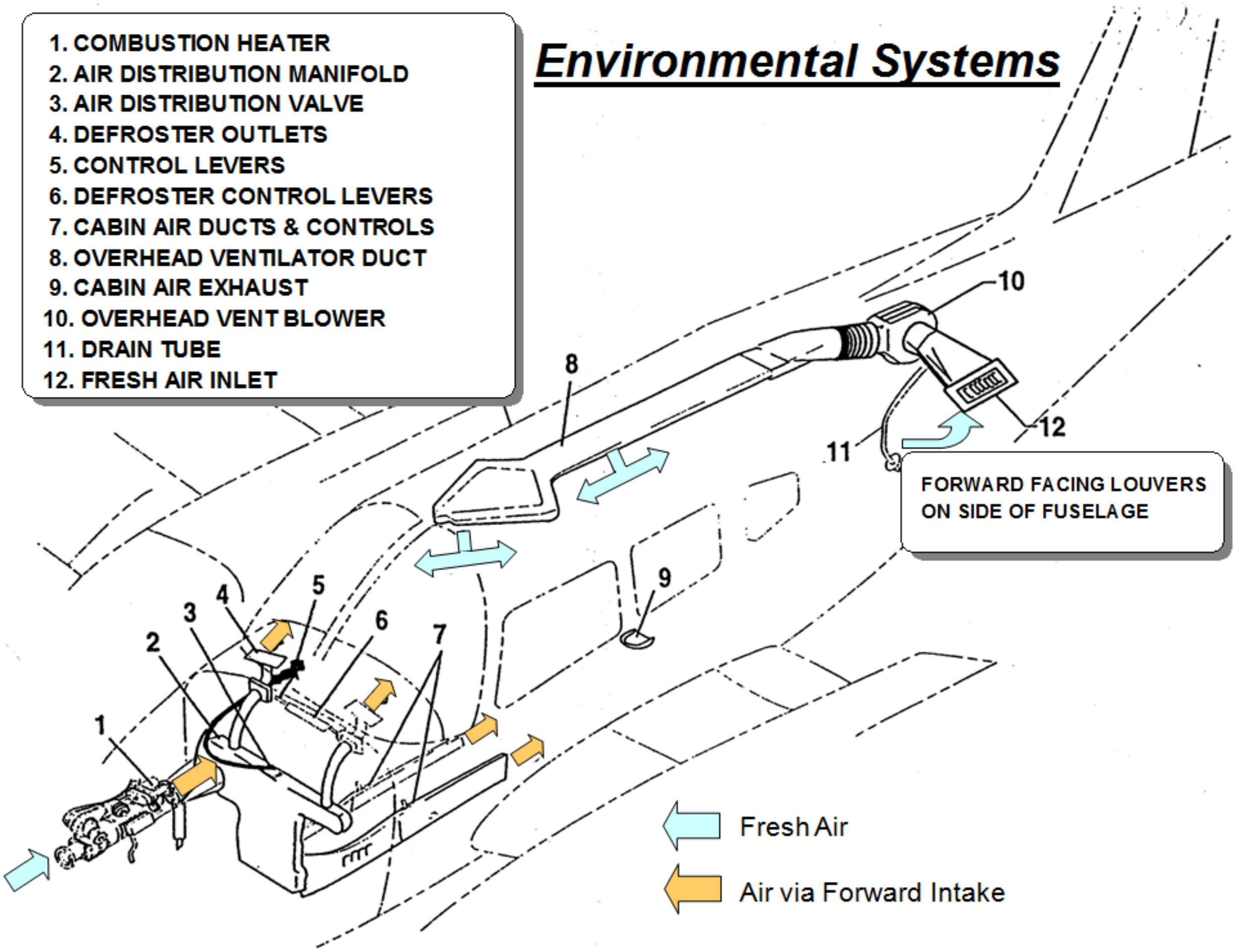
The pitot and static lines can be drained of water through drain valves located inside the cabin to the left of the pilot seat near the floor. To drain press the buttons in and any water in the lines will drain out the middle of the button.

An alternate static source located under the left side of the instrument panel will allow air from inside the cabin for static pressure. The cabin vents and storm window must be closed and the cabin heat and defroster must be on when using the alternate static source.

The pitot mast is also heated for de-icing or anti-icing if unintentionally encountering icing conditions in flight.
If the plane is equipped with autopilot, there may be additional static ports on the aft fuselage for use with that system.

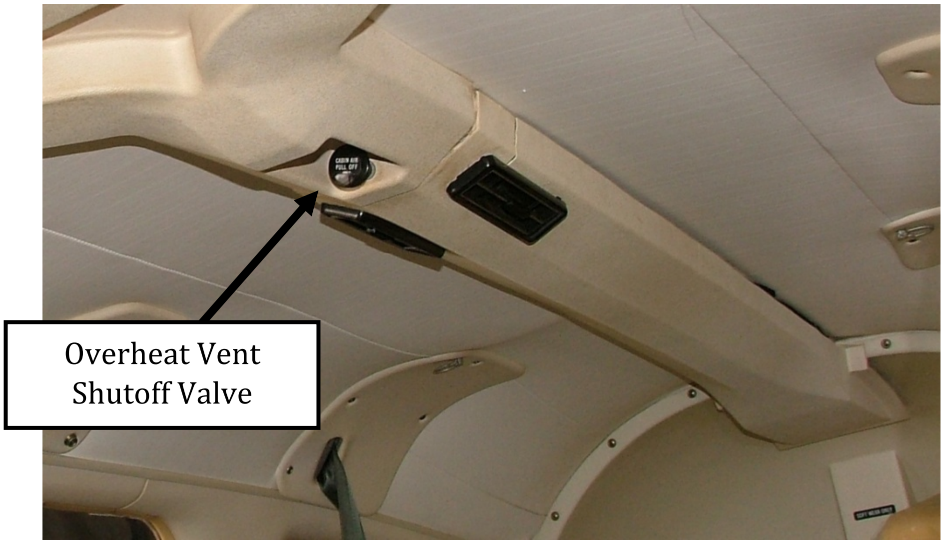
ENVIRONMENTAL

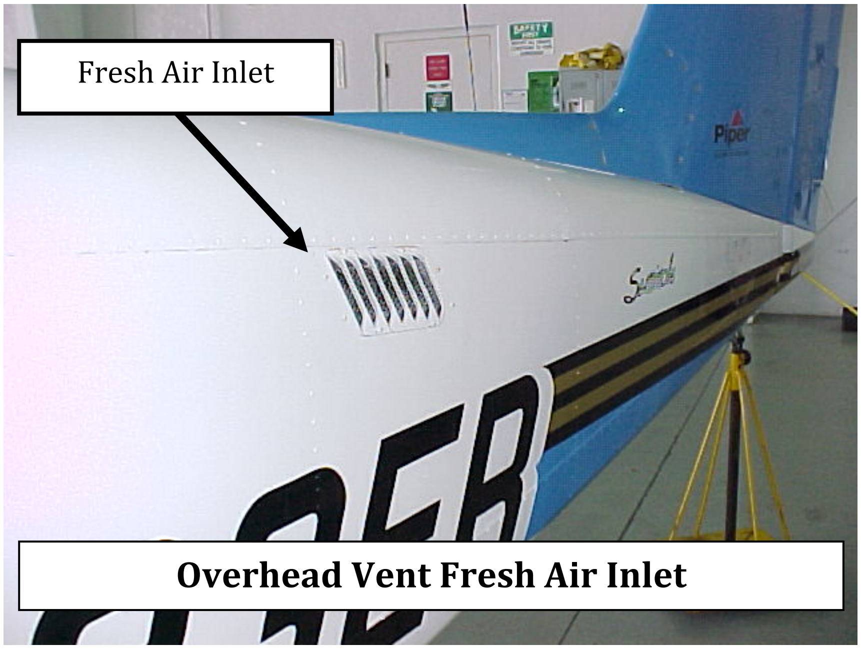
The environmental system provides both outside air and heated air for cabin heat and defrosters. There is an air blower near the tail of the airplane and a Janitrol combustion heater, which is located in the nose compartment of the airplane.



Both ram air through vents on the outside of the airplane and an air blower can move air through the overhead vents.

Overhead air vents and duct





Overhead Vent Fresh Air Inlet

The Janitrol combustion heater uses fuel from the left fuel tank at the rate of a ½ gallon per hour. (Make sure to account for this during flight planning). There is a fuel pump in the nose compartment to pump fuel from the left tank to the heater. The heater draws in outside air and uses a spark plug and fuel to make a “high velocity whirling flame”. The heat from this flame will heat air moving around a shroud around the heater and then push warm air into the cabin. This operates in similar principle to the cabin heat of a Cessna 172, however it does not involve engine exhaust at all. When the heater is on, heat should be felt right away.

Right Side of the Nose

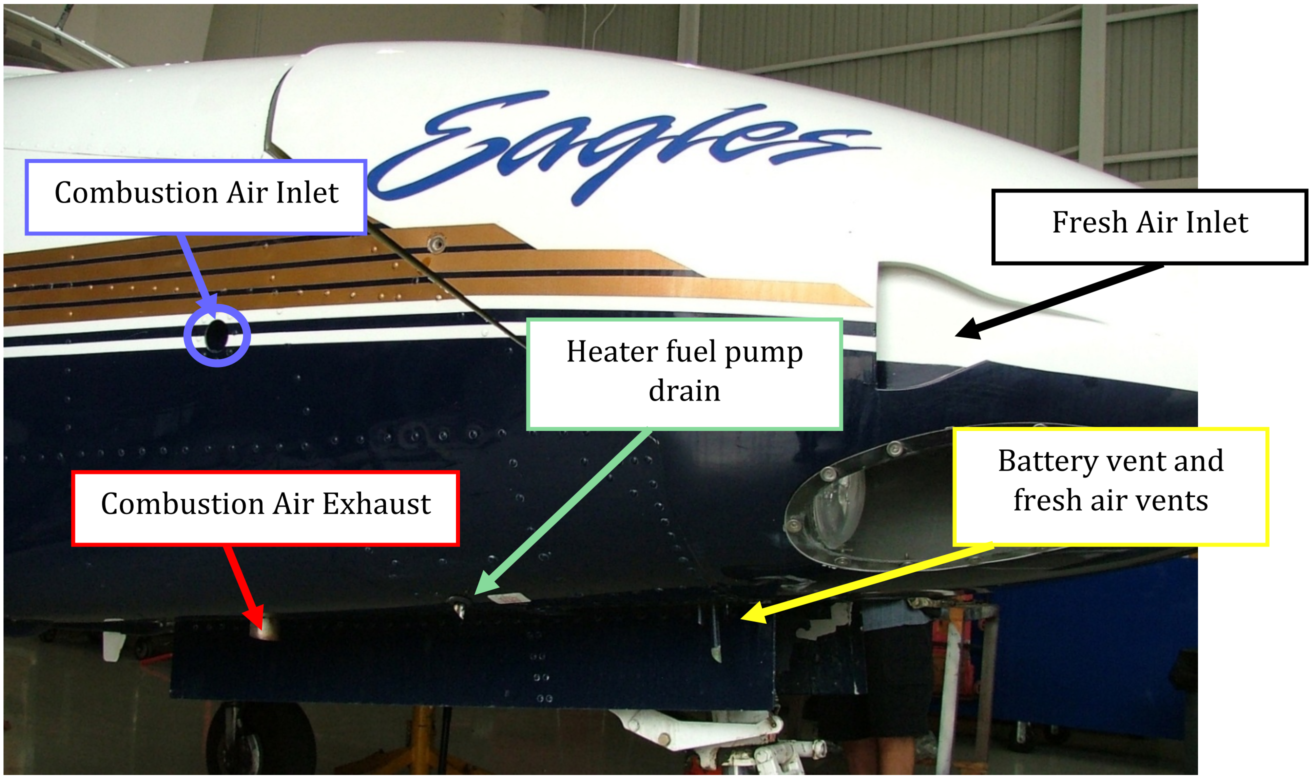
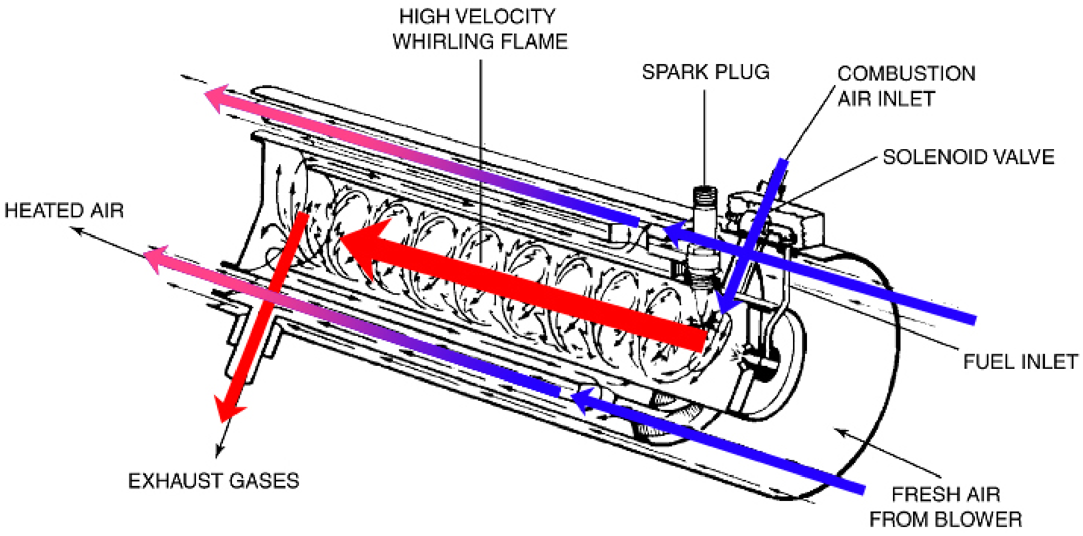
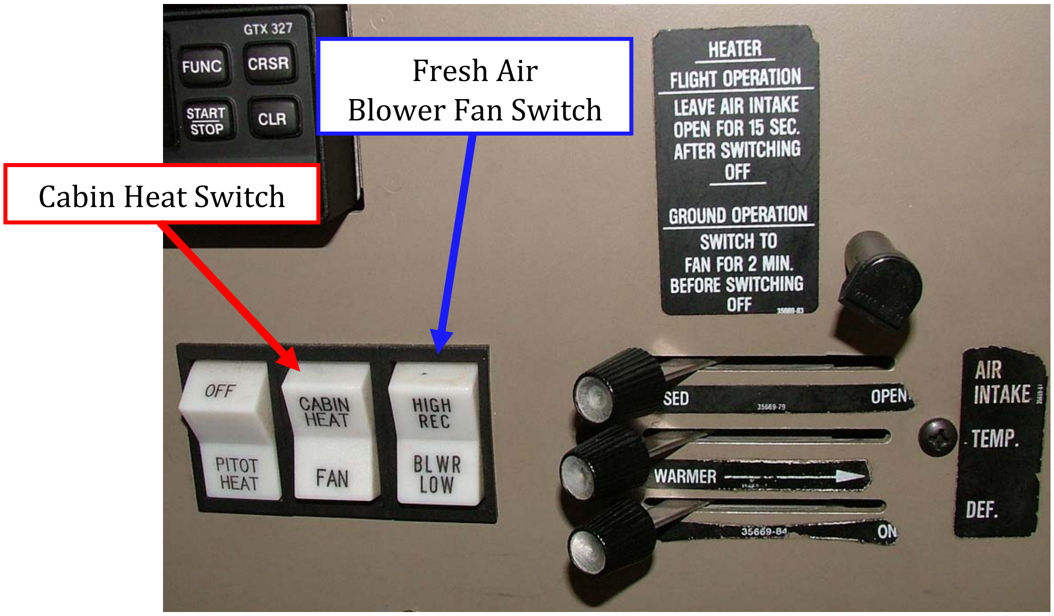


Diagram of the Inside of the Heater



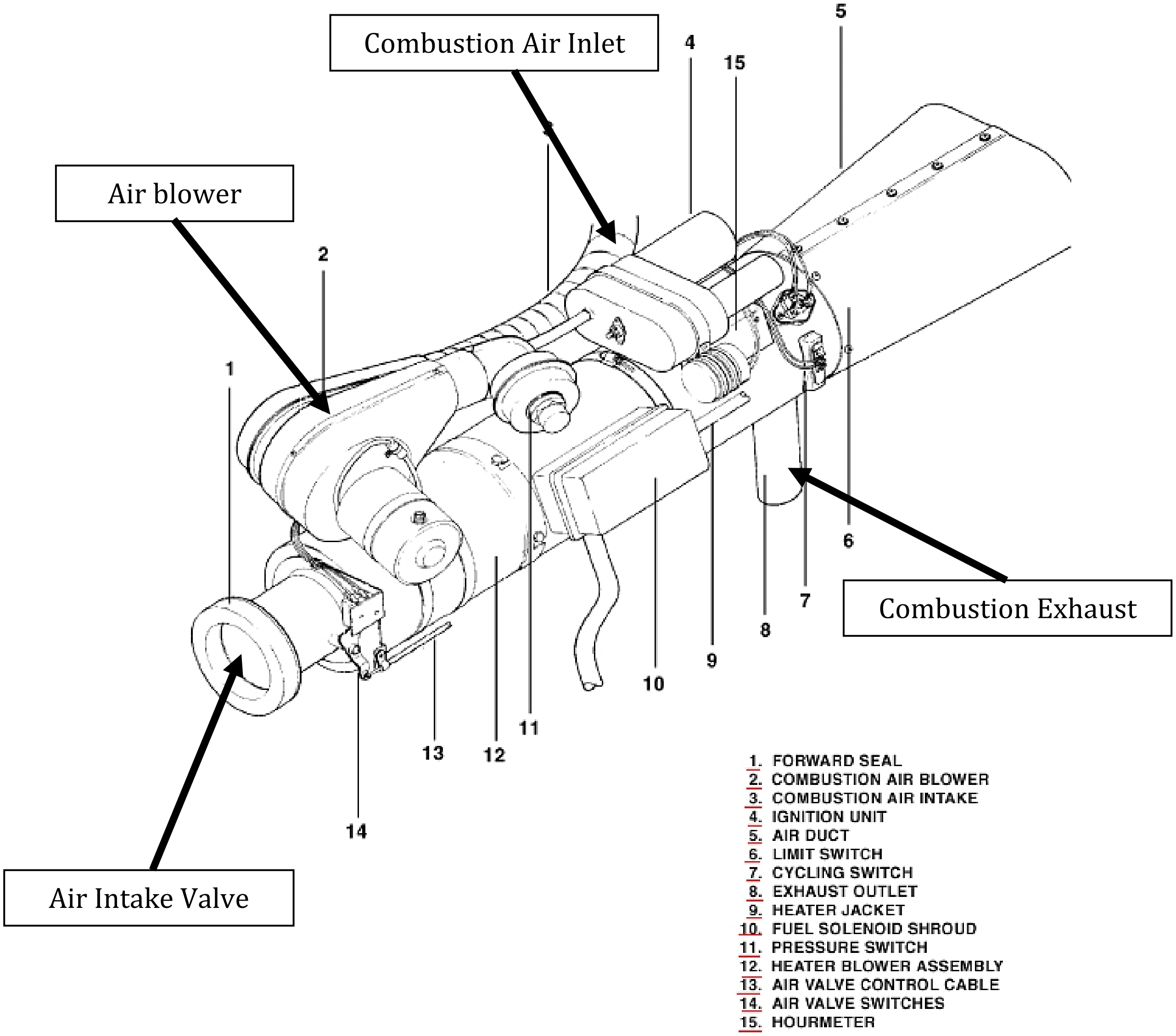
To turn the heater on, the cabin heat switch must be turned on AND the air intake lever must be in the open position. To turn on the defroster, with the heater on, move the defrost lever to the on position. The temperature of the heat is controlled by the temperature lever.

Environmental Controls



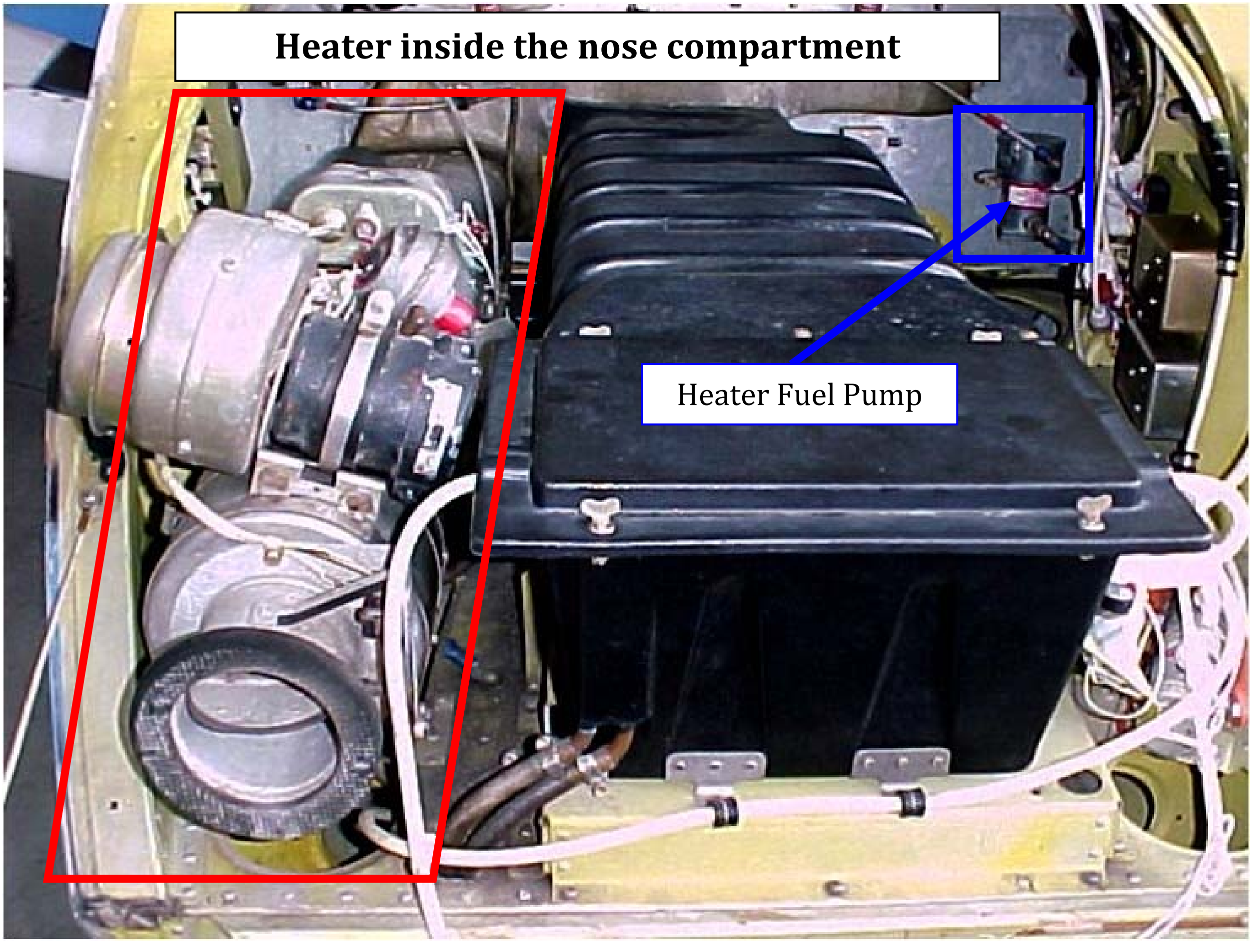
The temperature lever acts like the heat in a home, a temperature is set and the heat goes on until that temperature is reached then shuts off. When the temperature drops below the selected temperature the heater will automatically turn back on. The heater in the airplane cycles on and off the same way.

When the heat is turned on and the airplane is on the ground ram airflow is not flowing into the heater. There is a blower that will blow air from outside into the heater to be pushed into the cabin while on the ground. This blower shuts off when the up limit switch on the nose wheel is depressed (meaning the gear is up). When aloft the ram air from outside will push air into the heater and provide air for heating. The fan switch position can be used on the ground to blow fresh outside air into the cabin.



There is a overheat switch that acts as a safety feature to shut the heater off if the heater malfunctions. If an overheat happens the HTR OVER TEMP annunciator light will turn on and the heater will be automatically deactivated. Once the HTR OVER TEMP light illuminates the heater can only be reset on the ground by maintenance.

When turning off the heater in the air, turn the heat switch off and leave the air intake open for 15 seconds. If on the ground, turn the heater switch to the Fan position for two minutes. This will allow the heater to cool down after use. There is a placard on the instrument panel with this information as well.



ANNUNCIATOR PANEL AND WARNING LIGHTS

When does each light illuminate?	
OIL	When oil pressure on either engine is 15 psi and decreasing
VAC	When differential vacuum between pumps is 4 in Hg ±.25 in Hg
ALT	When either alternator output is zero
HTR OVERTEMP	When heater temperature in vent jacket is too hot
LO BUS	When system voltage drops from 14v to 12.5v (meaning only on battery power)

STALL WARNING

Stall warning vanes are activated when the airplane is airborne by the right squat switch. They cause an aural warning when airplane is approximately 5-10 knots above stall speed. The outboard stall warning vane operates when flaps are set at 0 or 10 degrees. The inboard stall warning vane operates when the flaps are set at 25 and 40 degrees.

EMERGENCY EXIT

The left window can be removed to be used as an emergency exit. To open the exit removed the plastic cover over the handle, pull the handle towards the nose of the airplane, and push the window out. The window will then free fall out of the frame. This exit should only be opened and used when on the ground.

EMERGENCY LOCATOR TRANSMITTER (ELT)

The ELT is located in the aft fuselage section of the airplane. It runs off its own self contained battery. The battery must be replaced after 1 hour of cumulative use, after it has been used in an emergency situation, or after the replacement date on the battery, which is half the shelf life of the battery. It can be tested during the first 5 minutes after the hour for no more than 3 audio sweeps. There is an automatic G-switch that will turn on the ELT after a hard landing or a crash, and a remote switch located on the instrument panel that can turn on the ELT anytime.

ELT located in the tail of the Seminole

406 MHZ ELT

Starting February 1, 2009 the ELT frequency 121.50 Mhz will not be monitored by a satellite. The frequency 406 Mhz will be used and monitored by a satellite. Local ATC towers and other local facilities will still monitor 121.50 Mhz from the ground, so they might hear the ELT alert, but it will not be monitored from space anymore. While it is not mandatory to switch to a 406Mhz ELT, there are some advantages:

	406 MHz Beacon – NEW	121.5/243 MHz Beacon
Signal	Digital: unique identification, registration data provides information on the owner or aircraft N#	Analog: no data encoded, higher false alert rate
Signal Power	5 Watts pulse	0.1 Watts continuous (typical)
Coverage	Global	Regional
Position Accuracy	Within 5 km (Doppler), 100m if GNSS (GPS) position is encoded in message	Within 20 km (Doppler only)
Alert Time	Geosynchronous satellite alert within 5 minutes	Waiting time for Low Earth Orbit satellite pass 45 minutes average
Doppler Position Ambiguity	Resolution possible at first satellite pass	Two passes required to resolve position ambiguity

SOURCES

Aeronautical Information Manual

FAA-H-8083-3 FAA Airplane Flying Handbook

FAA-H-8083-25 FAA Pilot's Handbook of Aeronautical Knowledge

Jeppesen Multi-Engine Manual

Piper Seminole Pilot's Operating Handbook

Piper Seminole Maintenance Manual

Title 14 of the Code of Federal Regulations

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APPENDIX

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