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# UNDERSTANDING

## LIGHT TWIN ENGINE AEROPLANES



Russ Evans



## C O N T E N T S

INTRODUCTION	Page 1
DEFINITIONS	Page 5
PERFORMANCE	Page 45
ENGINE FAILURE and ASYMMETRIC FLIGHT	Page 71

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# INTRODUCTION

WHILST IT IS TRUE TO SAY THAT "THE LIGHT TWIN  
ENGINE AEROPLANE OFFERS OBVIOUS SAFETY  
ADVANTAGES OVER A SINGLE ENGINE  
AEROPLANE," IT IS ALSO TRUE TO SAY THAT "THE  
LIGHT TWIN ENGINE AEROPLANE CAN BE MORE  
LETHAL".

The modern aeroplane represents one of the safest forms of transport, provided it is well maintained and operated in a responsible manner.

This book explains in practical terms what the pilot who wishes to fly the light twin engine aeroplane needs to know - hopefully the knowledge gained in reading the contents will improve the safety record of these aeroplanes and result in better, safer, and more competent twin engine pilots.

When the topic of light twins comes up in discussion, the subject of engine failures is invariably raised - but it is important to keep this in perspective, as engine failures rarely occur. The safety record of the single engine aeroplane is proof of such a statement.

Whilst the possibility of an engine failure in single or multi engine aeroplanes is therefore remote, failures can occur, and this is why the sequence is covered by the instructor during a pilot's initial or endorsement training.

To fully appreciate the light twins, it is essential to understand their **PERFORMANCE** capabilities, particularly in the area of asymmetric flight, which is flight following an engine failure.

This book also examines some of the "figures" which appear in the aeroplane's Flight Manual, the Manufacturer's Data Manual and Pilot's Handling Notes - figures which sometimes can be misleading, as too often they only represent the results obtained by the Manufacturer's test pilot at the time of the initial **CERTIFICATION** of the aeroplane.

The options available to a pilot should an engine fail during flight will also be discussed - the aim being to get rid of the intrigue and mystery which currently surrounds asymmetric flying.

It is of interest to note that, whilst twin engine aeroplanes are involved in fewer engine related accidents than single engine aeroplanes, the percentage of fatalities and serious injuries is much higher with twin engine aeroplanes.

Analysis of these accidents confirm that in most cases, this can be attributed to :

1. Pilots' inadequate knowledge of the **PERFORMANCE CAPABILITIES** of the light twin aeroplanes, particularly in the area of asymmetric flight
2. Failure to understand and correctly interpret the **PERFORMANCE MATERIAL** normally supplied by the Manufacturer and documented in the aeroplane's Flight Manual
3. Stall spin accidents, and other training accidents which too often result when inexperienced Flight Instructors inadvertently create **ACTUAL EMERGENCY SITUATIONS** during training or recurrent training



4. "Token endorsements", with little or no time being devoted to ground briefings - something hard to understand when most of the endorsements are completed by qualified Flight Instructors
5. Insufficient recurrent training in engine failure emergency procedures

In a single engine aeroplane, pilots know that in the event of an engine failure during flight, they have but one option, and that is to make an emergency landing.

If the same mechanical failure occurs to an engine of a light twin engine aeroplane, the pilot **MAY** in certain circumstances, have more than one option. This, however, will depend on the performance capability of the aeroplane and when and where the malfunction occurs.

In many circumstances, pilots who have no true appreciation of the performance capabilities of the aeroplane being flown, and those who have been inadequately trained, would be far better off in a single engine aeroplane as too often, if faced with an engine failure, complete loss of control occurs whilst the pilot endeavours to keep the twin engine aeroplane flying.

The intent of this book is to explain, in simple and practical terms, what the light twin engine aeroplane **CAN** and **CANNOT** do, and to take the intrigue out of asymmetric flight should an engine fail during flight.

To achieve these objectives, the book examines and analyses :

1. **DEFINITIONS** which relate to twin engine aeroplanes that need to be understood
2. What a pilot needs to know about the **PERFORMANCE CAPABILITY** of the light twin
3. How some of the **PERFORMANCE DATA** which appears in the Flight Manual and the Manufacturer's Manual, whilst technically correct, can be misleading
4. **ENGINE FAILURE** and **ASYMMETRIC FLIGHT** - the options available and the correct procedure to follow

**NEVER FORGET THAT THE BEST INSURANCE YOU, AS A PILOT, CAN HAVE IS TO KNOW YOUR OWN LIMITATIONS, AND THE LIMITATIONS OF THE AEROPLANE TO BE FLOWN.**

## **DEFINITIONS**

Before we discuss the performance criteria and the certification standards for the light twin piston engine aeroplane, there are certain definitions which need to be explained and understood.

### CRITICAL ENGINE

The **CRITICAL ENGINE** is the engine which, if it fails during flight, has the most adverse effect on the control and performance of the aeroplane.

The engine which **DOES NOT** produce the greater yawing and rolling characteristics is therefore the **CRITICAL ENGINE**.

THE **CRITICAL ENGINE** IS DEPENDENT UPON THE DIRECTION OF ROTATION OF THE PROPELLERS.

The **LEFT** engine is the **CRITICAL ENGINE** in aeroplanes which have clockwise rotating propellers when viewed from the cockpit or from behind the aeroplane. This is the case with most American built propeller driven aeroplanes.

Exceptions are aeroplanes with contra rotating or turning propellers, like Piper Seneca, Beech Duchess or push-pull twins like the Cessna Skymaster. With contra rotating propellers, there is **NO CRITICAL** engine. As far as the Skymaster is concerned, the rear engine is considered critical since the "pusher" propeller is more effective than the "tractor" or front propeller. Unfortunately, however, quite often failure of the rear engine in this aeroplane may go unnoticed by the pilot unless he is closely monitoring his instruments.



Diagram 1

When a wing mounted engine fails during flight whilst the aeroplane is under power, two things happen unless they are prevented by the pilot :

1. The aeroplane will want to yaw towards the failed engine
2. It will also want to roll towards the failed engine

This yawing characteristic is understandable as it is the direct result of the asymmetry of the thrust line. Coupled with this is the fact that the propeller of the failed engine, whilst windmilling, also creates considerable drag and this additional drag further compounds the yawing tendency already being produced by the operating engine.

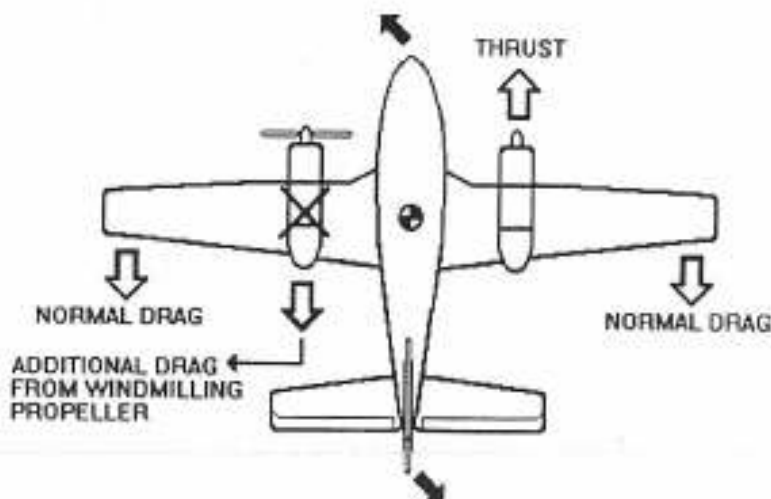


Diagram 2

The amount of yaw will also be dependent upon :

1. The amount of thrust being produced by the operating engine
2. The position of the engine in relation to the aeroplane's longitudinal axis, i.e. the further out an engine is positioned on the aeroplane's wing, the greater its yawing moment. This is why the aeroplane designers try to place the engines as close to the fuselage as the design requirements will permit.
3. The distance between the thrust line produced by the operating engine and the aeroplane's Centre of Gravity (C of G) - the thrust line is explained later in this book
4. The rate of thrust decay of the failed engine
5. The type of propeller attached to the engine
6. The aeroplane's directional stability - aeroplanes with good directional stability actually tend to oppose the asymmetric yawing
7. Which engine fails



The yawing tendency can be very pronounced and the greatest effect occurs when the aeroplane is operating at high power settings, high angles of attack, and at relatively low airspeeds - the type of situation which exists following take-off. There are also airspeeds below which yaw, as a result of an engine failure, cannot be controlled even with the application of full rudder and, in these circumstances, directional control will be lost - hence flight at or near these speeds must be avoided.

Different rudder forces are also required to control the yaw, and these forces can vary and are dependent on which engine fails.

It is correct to say that should an engine fail in a twin engine aeroplane, the yawing which occurs, unless prevented or controlled by the pilot, is the primary cause of most asymmetric handling problems.

### **ALWAYS REMEMBER THAT IT IS THE RUDDER THAT PREVENTS OR CONTROLS THE YAW.**

The second problem is that the aeroplane, besides yawing, will want to roll towards the failed engine - the reason being that when the aeroplane yaws, the outer wing travels faster than the inner wing, and hence generates more lift. This extra lift causes a rolling action towards the inoperative engine and, unless the yaw itself is arrested, the nose of the aeroplane will eventually drop and turn towards the lower wing - a situation which must not be allowed to develop.

### **ROLLING MOMENTS IN ASYMMETRIC FLIGHT**

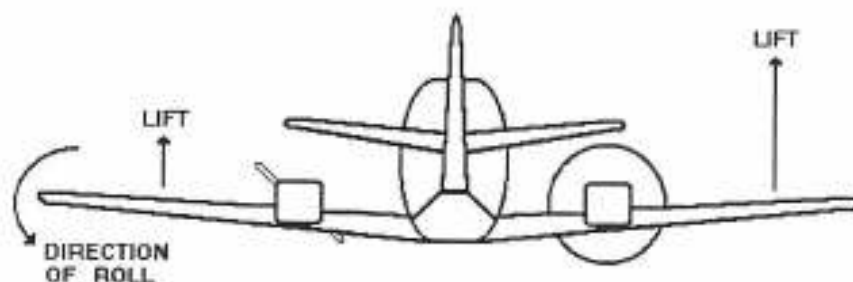


Diagram 3

If a pilot introduces aileron to prevent the rolling tendency in an endeavour to keep the wings level whilst the aeroplane is yawing, or attempts to lower the wing **TOWARDS** the operating engine to eliminate aerodynamic slip (discussed later), many aeroplanes will suffer from the effect of aileron drag. This aileron drag will cause further yawing and hence a greater rolling tendency. If such a situation is allowed to continue, subsequent loss of control is likely to occur. Ailerons **MUST NOT** be introduced whilst the aeroplane is yawing, otherwise the situation will only further deteriorate.

Additionally, because the slipstream is lost from the wing area behind the propeller of the failed engine, a small but significant loss of lift from that wing area occurs and therefore, a condition of unequal lift between the two wings will result. The resulting rolling effect is usually small and normally well within the ability of the ailerons to counter, except possibly at low speeds or when high lift flaps are used. It does however contribute to the rolling tendency.

As a result of the asymmetric yawing moment, an additional loss of air-flow will also occur over the wing area on the same side as the failed engine due to the blanketing effect of the fuselage and, once again, this further loss of lift can contribute to the aeroplane's rolling.

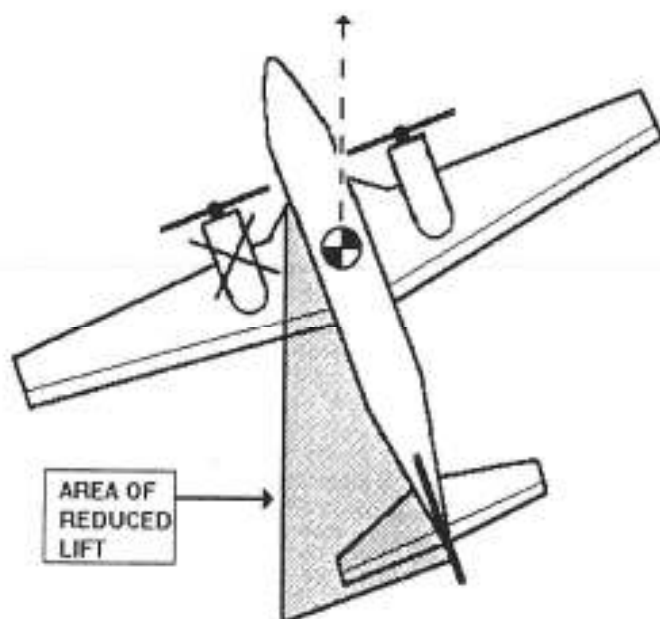


Diagram 4

The effect of **PROPELLER TORQUE** which increases with power, will also tend to roll the aeroplane in the opposite direction to that of propeller rotation. In the case of clockwise rotation, both engines cause a roll to the left. When the left engine fails, the torque effect assists the yawing moment while it opposes the yawing moment when the right engine fails.



Diagram 5

Now let us examine why the **LEFT** engine is the **CRITICAL** engine in aeroplanes with propellers which rotate clockwise.

There are three contributing factors - namely:

1. Offset Thrust
2. Torque Effect
3. Slipstream Effect

### 1. OFFSET THRUST

- a/ What do we mean by **OFFSET THRUST** and
- b/ What is its role in the determination of the **CRITICAL ENGINE**

The blades of propellers are the equivalent of small aerofoils and are dependent on an angle of attack to achieve "lift", and "lift" from propellers means **THRUST**.

Provided the plane of rotation of the propellers is at **RIGHT ANGLES** to the relative airflow, the centre of thrust for each engine or, as it is normally called, the **THRUST LINE** for each engine is through the fore and aft centre of the engine (or the hub of the propeller), as can be seen in the following diagram.

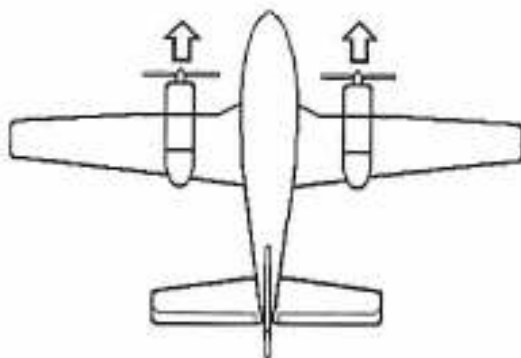


Diagram 6

If however the plane of rotation of the propellers is **NOT** at right angles, but is at a **POSITIVE** angle to the relative airflow, or the aeroplane's path of flight - an example of this would be flying straight and level at a low airspeed ( i.e. a high nose position ) - the **DOWNGOING** (or descending) propeller blades are at a **GREATER** angle of attack to the relative airflow than the **UPGOING** (or ascending) blades. Consequently, they produce more lift and hence more thrust and, instead of the **THRUST LINE** acting through the centre of the engine (or the hub of the propeller), it moves to the **RIGHT**. This is referred to as an **OFFSET THRUST LINE**.

Diagram **A** below schematically shows the angle of attack of the aeroplane's **DOWNGOING** propeller blade when the plane of rotation is at **RIGHT** angles to the relative airflow, whilst diagrams **B** and **C** show what happens when the propeller is operating at a **POSITIVE** angle of attack to the relative airflow.

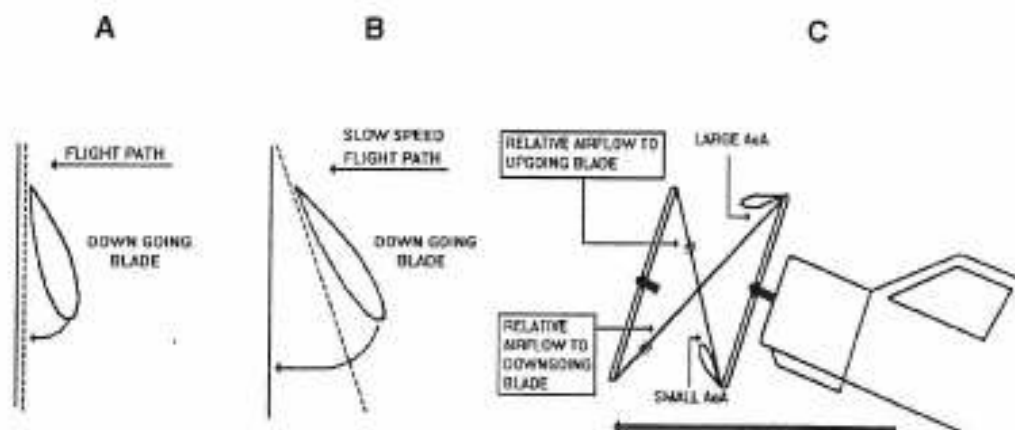


Diagram 7

In diagram **A** the **THRUST LINE** operates through the propeller hub, whilst in diagrams **B** and **C** the **THRUST LINE IS OFFSET**. In the case of **CLOCKWISE** rotating propellers when viewed from the cockpit, the **THRUST LINE** will be offset to the **RIGHT** as can be seen in the following diagram.

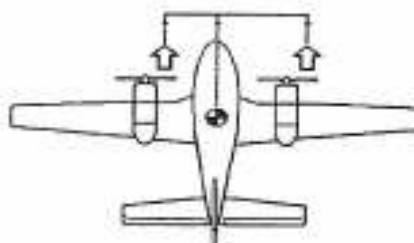


Diagram 8



Now whilst we used "straight and level flight at low speed" to provide an example of when propellers would be operating at a positive angle to the relative airflow, there are many other occasions when the same situation exists. Many aeroplanes, due to their design or the way the engine(s) are installed, always have propellers operating at a positive angle of attack even during "normal" flight. In these circumstances, the manufacturer counteracts the effect of the offset thrust line in the aeroplane design, but this can only be done to a limited degree and is why rudder trimming devices are installed.

Following an engine failure during flight which requires the "angle of attack" to be increased to maintain the aeroplane's performance, the thrust line will always move to the right in aeroplanes with clockwise rotating propellers.

Let's look at another explanation of **OFFSET THRUST**.

Consider what happens to a **TAILWHEEL** aeroplane on take-off.

At the start of the take-off run, when the tail of the aeroplane is still on the ground, the propeller shaft is inclined upwards and the plane of rotation of the propeller is therefore operating at a positive angle of attack to the relative airflow.

As a result of this positive angle of attack, the downgoing blade of the propeller will be at a greater angle of attack than the upgoing blade, and it will produce more lift and hence more thrust due to the **OFFSET THRUST LINE**. The aeroplane (with the propeller rotating clockwise as seen from the cockpit) will want to yaw to the left while the tailwheel is still on the ground.

#### DOWNGOING BLADE PRODUCES MORE THRUST WITH THE TAIL ON THE GROUND



Diagram 9

If we relate this situation to a twin engine aeroplane flying relatively slowly with a high nose attitude, the same principle holds true.

In summary, it can be said that:

1. Provided the plane of rotation of the propellers is at **RIGHT** angles to the relative airflow, the thrust line for each engine is through the fore and aft centre of the engine (or hub of the propeller).
2. If the plane of rotation of the propellers is at a **POSITIVE** angle of attack to the relative airflow, the downgoing propeller blades are now operating at a **GREATER** angle of attack to the relative airflow than the upgoing blades. As a result, the downgoing blades produce more lift, and hence more thrust, and this causes the **THRUST LINE** to be offset to the **RIGHT** - this situation is also referred to as "**P**" factor.

Now, having explained the meaning of offset thrust and the resulting offset thrust line, let us see why it is an important factor in the determination of the **CRITICAL ENGINE**.

As can be seen from the following diagram, when the propellers are operating at right angles to the relative airflow, the thrust line operates through the centre of the engine (or the hub of the propeller).

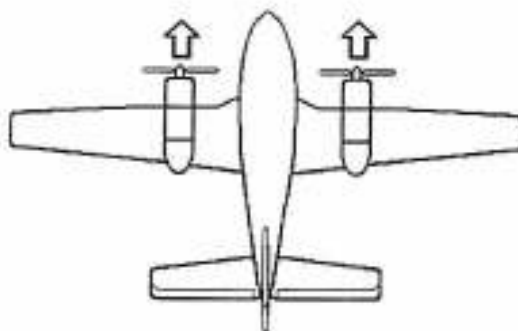


Diagram 10

If however the propellers are operating at a **POSITIVE** angle of attack to the relative airflow, we know that the thrust line is now **OFFSET** to the right.

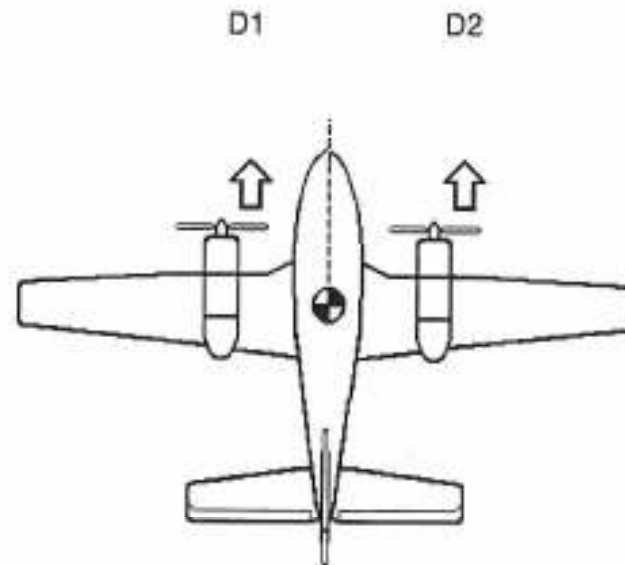


Diagram 11

Whilst the forward pull of D1 (downgoing propeller blade of the left engine) is the same as D2 (downgoing blade of the right engine), the downgoing blade of the right engine (D2) is further from the fuselage than the downgoing blade of the left engine (D1). In situations where the aeroplane was being flown in a manner which resulted in the propellers being at a positive angle of attack to the relative airflow (e.g. flying straight and level at a low airspeed), there would be a need to adjust the rudder trim to correct for the tendency of the aeroplane to yaw to the left.

Now should the left engine fail during flight (i.e. the right engine operating), there will be a greater yaw and roll tendency than if the left engine was operating and the right engine had failed - simply because the thrust line of the right engine is further from the longitudinal axis of the aeroplane than the thrust line of the left engine. It can also be seen that the turning moment of D2 is much greater than the turning moment of D1. This is one of the reasons why loss of power from the left engine in aeroplanes with clockwise rotating propellers causes the greatest problem, and **WHY** the **LEFT** engine is considered to be the **CRITICAL ENGINE**.

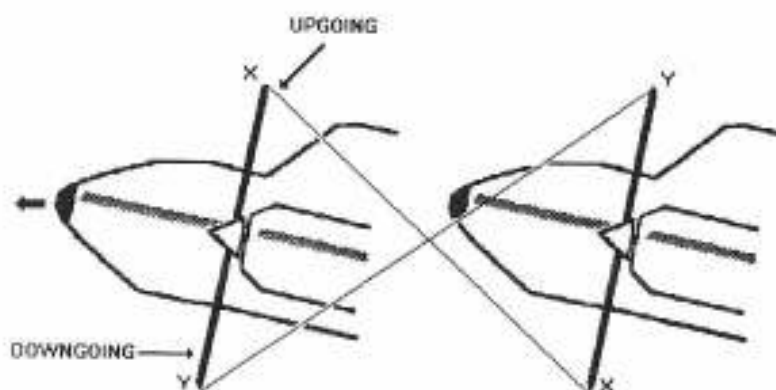
An interesting situation also occurs when we consider the path of the individual blades relative to the airflow.

It is obvious that both propeller blades have the same rotational speed, such as 2400 rpm or whatever happens to be set. If the aeroplane is flying with a high nose attitude (which would be the case if one engine happened to fail and the pilot was trying to climb or maintain height), the propeller on the operating engine is no longer operating at 90 degrees to the relative airflow but is now operating at a positive angle of attack to the relative airflow.

As diagrams 12A and 12B show, during the time the aeroplane moves from position A to position B, the downgoing propeller blade travelled a greater distance than the upgoing propeller blade. This means that the downgoing blade must be travelling faster and hence producing more lift and thrust than the upgoing propeller blade (similar situation to what happens to the outer wing during a turn).

X--X is the distance  
travelled by the  
**UPGOING** propeller  
= 4.6mm.

Y--Y is the distance  
travelled by the  
**DOWNGOING** propeller  
= 5.6mm.



Position B

Position A

Diagram 12B

Diagram 12A



This is possible because of the properties of rotational motion, as the downgoing blade - when it reaches its furthest point of travel - changes to the upgoing blade. As the downgoing blade travels faster (and is on the right hand side), this is another reason why the thrust line is offset to the right when the aeroplane is flying with a high nose attitude with the propellers at a positive angle of attack to the relative airflow.

Hence the failure of the **LEFT** engine again means there is a greater yawing and rolling tendency than in the case of failure of the **RIGHT** engine as a result of the **OFFSET THRUST LINE**.

If, however, the plane of rotation of the propellers is at a **NEGATIVE** angle of attack to the relative airflow, (one example could be when flying straight and level at a higher than normal airspeed), it is now the upgoing propeller blade which produces the greatest lift and thrust and it is the **RIGHT** engine which becomes the **CRITICAL ENGINE**. The aeroplane in these circumstances will want to yaw to the right if it is operating in a normal two engine configuration. If however an engine were to fail and performance is to be retained, once again the nose of the aeroplane would need to be raised (or the angle of attack of the aeroplane would need to be increased). As a result, the plane of rotation of the propellers would be at a positive angle of attack to the relative airflow, hence the **LEFT** engine again becomes the **CRITICAL ENGINE**.

**REMEMBER**, the most critical phase of flight in the event of an engine failure is during and immediately after take-off. This is when the aeroplane has a large angle of attack, high power and relatively low airspeed.

So ends our discussion of **OFFSET THRUST** and its significance in determining the **CRITICAL ENGINE**.

Now let us examine how the effects of **TORQUE** and **SLIPSTREAM** are factors which also contribute to the **LEFT** engine being the **CRITICAL ENGINE** in aeroplanes with **CLOCKWISE** rotating propellers.

## 2. TORQUE EFFECT

**TORQUE** effect is the reaction that makes the aeroplane roll in the opposite direction to the propeller rotation. In the case of clockwise rotation, both engines cause a roll to the left. When the **LEFT** engine fails, the torque effect **ASSISTS** the yawing moment, whilst it **OPPOSES** the yawing moment when the **RIGHT** engine fails. Thus the **LEFT** engine is again the **CRITICAL** engine.



Diagram 13

## 3. SLIPSTREAM EFFECT

The following diagram shows that, with clockwise rotating propellers, the slipstream from the **LEFT** propeller strikes the fin and **AIDS** the effectiveness of the rudder, whereas the slipstream from the **RIGHT** propeller does not. Hence, once again, failure of the **LEFT** engine is more critical than failure of the **RIGHT** engine.

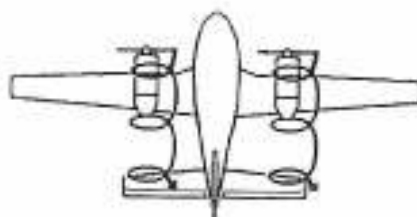


Diagram 14

In summary, it can be said that the **LEFT** engine is the **CRITICAL ENGINE** in the event of an engine failure during flight in aeroplanes with clockwise rotating propellers, irrespective of the aeroplane's configuration prior to the engine failure.

The reasons :

1. The **OFFSET THRUST LINE** which is the direct result of the aeroplane being flown or operated at a positive angle of attack where the plane of rotation of the propellers is **NOT AT RIGHT ANGLES** to the relative airflow
2. The effect of **TORQUE** and
3. The effect of **SLIPSTREAM**

The most critical situation occurs when the aeroplane is being operated at high angles of attack, high power settings and low airspeeds - a situation which exists immediately following take-off.

So ends our explanation of the **CRITICAL ENGINE**.

### MINIMUM CONTROL SPEED AIRBORNE - $V_{mc(a)}$

$V_{mc(a)}$  is designated by the **RED** line on the airspeed indicator and this red line indicates the **MINIMUM CONTROL SPEED** when airborne at **SEA LEVEL**.

By **definition**,  $V_{mc(a)}$  is the minimum calibrated airspeed (CAS) at which, when the **CRITICAL ENGINE** of a multi engine aeroplane is suddenly made inoperative, it is possible to recover directional control of the aeroplane within 20 degrees heading change and, thereafter, maintain straight flight with not more than 5 degrees of bank towards the operating engine. During recovery, the aeroplane should not assume any dangerous attitude nor should it require exceptional piloting skill, strength or alertness on the part of the pilot.  $V_{mc(a)}$  must not exceed 1.2  $V_s$  (the stall speed with the flaps in the take-off position and gear retracted) and the foot loads for aeroplanes in excess of 5,700 kgs for FAA (American) Certification, must not exceed 180 lbs (81.6 kgs). For aeroplanes up to 5,700 kgs, the following figures apply :

<u>Forces Applied to Rudder Pedals</u>	<u>Kgs Force</u>	<u>Lbs Force</u>
Temporary Application	68	150
Prolonged Application	10	22

In simple terms,  $V_{mc(a)}$  is the speed beyond which the aeroplane will yaw and roll uncontrollably towards the windmilling propeller and, unless prompt corrective action is taken before this happens, loss of control is inevitable.

$V_{mc(a)}$  is often referred to as  $V_{mc}$  and, whilst this is acceptable, it is technically incorrect as in larger aeroplanes there is normally a requirement to establish  $V_{mc(g)}$  (Minimum Control Speed Ground).  $V_{mc(g)}$  however has no significance in the smaller twin engine aeroplanes we are discussing.

The published  $V_{mc(a)}$ , obtained by the test pilot, is a "certification performance/controllability speed" intended to be the basis for determining the operating procedures concerned primarily with controllability and only indirectly with performance.

In determining the  $V_{mc(a)}$  for certification requirements, the manufacturer's test pilot is required to configure the aeroplane as follows:

1. Take-off power on both engines
2. Maximum all up weight
3. Rearmost allowable Centre of Gravity
4. Flap in take-off position



5. Cowl flaps set for take-off
6. Trim set for take-off
7. Aeroplane airborne and out of ground effect
8. Landing gear retracted

To determine the value of  $V_{mc(a)}$ , the test pilot, with take-off power on both engines, stabilises the aeroplane at a speed, and he then fails the CRITICAL engine using the mixture control - the propeller of the "critical" engine is now windmilling, (when an aeroplane has an automatic feathering device however, the propeller is feathered) and the aim is then to try to hold airspeed and heading. This procedure is called a DYNAMIC engine cut.

At the manufacturer's discretion, a bank angle of not more than 5 degrees towards the operating engine may be used.

Starting at an airspeed well above  $V_{mc(a)}$ , the test pilot and his crew go through a series of these engine cuts, each at a slightly lower airspeed until they are no longer able to hold the heading within 20 degrees when the engine is failed. The process is repeated at a number of altitudes which result in higher airspeed readings as the altitudes decrease. These values are then plotted on a graph and a line drawn through the points. By extrapolating this line to sea level, the published  $V_{mc(a)}$  is determined.

It can therefore be seen that the  $V_{mc(a)}$  speed was obtained using a very cautious technique, and one that is not factored for any element of surprise. It must also be remembered that this information was obtained by an experienced test pilot, fully aware of the intent of the particular flight, whilst using the new aeroplane "selected" by the manufacturer. The test was also completed in daytime in ideal flight conditions i.e. there was no turbulence, and there was no factoring for piloting skill or aeroplane condition.

Despite what the definition of  $V_{mc(a)}$  states, **THE AVERAGE PILOT CANNOT BE EXPECTED TO CONTROL THE AEROPLANE SAFELY AT  $V_{mc(a)}$** , especially in critical or adverse circumstances, as any small handling error could lead to serious consequences.

In any discussion or demonstration of  $V_{mc(a)}$ , it is also important to always appreciate and remember that **SOME AEROPLANES WILL NOT MAINTAIN LEVEL FLIGHT AT OR NEAR  $V_{mc(a)}$ , LET ALONE CLIMB OR TURN, and SOME AEROPLANES WILL EVEN STALL BEFORE REACHING  $V_{mc(a)}$ .**

Provided an aeroplane has not reached the  $V_{mc(a)}$  for its configuration, and the stall speed of the aeroplane is lower than  $V_{mc(a)}$ , a pilot should be able to make at least a controlled descent and, in some circumstances, that is all that can be expected. Enough emphasis cannot be placed on the importance of avoiding flying at speeds near to  $V_{mc(a)}$  as, should directional control be lost with one engine inoperative, a stall or spin is likely to occur.

Although most pilots of twin engine aeroplanes realise that proper airspeed must be maintained under all circumstances, the inadequately trained pilot or the pilot who has allowed his skills to deteriorate, will often find it psychologically unpalatable to lower the nose to maintain airspeed and control while the aeroplane is flying close to the ground. This reluctance to lower the nose when the speed is close to  $V_{mc(a)}$  has resulted in many loss of control accidents when a pilot has attempted to "coax" the aeroplane into staying in the air at the expense of airspeed. This factor is perhaps the single greatest cause of accidents involving engine failure following take-off, and surprisingly enough, accidents involving loss of control after engine failure at altitude during cruise flight i.e. stall/spin accidents.

It must be appreciated that, whilst the manufacturer is required to determine the  $V_{mc(a)}$  with the aeroplane configured as mentioned previously, sudden engine failure rarely occurs with all the requirements stipulated for the actual flight test, and therefore  $V_{mc(a)}$  cannot be considered as a static figure. Again, pilots must realise that the aeroplane they are flying often is not to the same standard as far as presentation, performance etc. as the new aeroplane being used by the manufacturer's test pilot. Always remember that the published  $V_{mc(a)}$  is the  $V_{mc(a)}$  the manufacturer is required to establish for **CERTIFICATION** purposes.

The main theme of any discussion regarding  $V_{mc(a)}$  is for pilots to appreciate what  $V_{mc(a)}$  is all about. Unfortunately, too many accidents can be attributed to inexperienced instructors trying to demonstrate  $V_{mc(a)}$  using the methods of the test pilot, and this has resulted in loss of control of the aeroplane. Also, remember that if the aeroplane's stalling speed is close to  $V_{mc(a)}$  and the stall actually occurs during the demonstration, there is every possibility of a stall/spin situation and every chance of this resulting in a fatal accident.

In training, the **THROTTLE** of the critical engine (**NOT** the mixture control) should be closed by the instructor at or above  $V_{sse}$  ( $V_{sse}$  is a guidance recommended safe single engine airspeed) or, where  $V_{sse}$  is not specified, at a safe margin above  $V_{mc(a)}$ . The power on the operating engine is then smoothly increased until full throttle, or maximum continuous power, is set. Airspeed is then reduced slowly (one knot per second) until directional control of the aeroplane can no longer be maintained - the trainee should now be able to recognise the approach of  $V_{mc(a)}$ , and see an actual  $V_{mc(a)}$  situation.

Also remember that, because  $V_{mc(a)}$  at altitude is lower than the sea level published  $V_{mc(a)}$ , there is the possibility that  $V_{mc(a)}$  could now be less than the aeroplane's actual stalling speed - a situation which did not exist at sea level and even at some lower altitudes.

The method of demonstrating  $V_{mc(a)}$  just described, is the determination of the **STATIC**  $V_{mc(a)}$ . The **DYNAMIC** engine cut procedure used by the test pilot to determine  $V_{mc(a)}$ , where simulated engine failure was achieved using the mixture control at the actual  $V_{mc(a)}$  speed, **SHOULD NOT** be attempted - as in doing so, an actual "emergency" situation is being created which could have serious consequences.

**REMEMBER THE  $V_{mc(a)}$  SPEED PROVIDED BY THE MANUFACTURER IS A SEA LEVEL CALIBRATED AIRSPEED WITH THE AEROPLANE BEING FLOWN IN A "SPECIFIED" CONFIGURATION. IT IS A SPEED REQUIRED TO BE DETERMINED AS PART OF THE AEROPLANE'S CERTIFICATION.**



Let us now list and discuss some of the factors which will result in different  $V_{mc(a)}$  speeds.

1. Power available
2. Critical engine
3. Centre of Gravity
4. Altitude
5. Air temperature
6. Aeroplane configuration
  - a/ Landing gear
  - b/ Flaps
  - c/ Cowl flaps
  - d/ Propeller drag - effect of feathering
7. Turbulence and wind gusts
8. Pilot reaction and strength
9. Pilot experience
10. Weight
11. Electrical loads and airconditioning
12. Degree of bank applied towards the operating engine

### 1. POWER AVAILABLE

The force producing the yaw is proportional to the thrust from the operating engine. Therefore, at a given IAS (Indicated Air Speed), more rudder will be required to maintain directional control if the thrust is increased. The greater the thrust from the operating engine, the higher will be the IAS at which directional control is lost.

### 2. CRITICAL ENGINE

As we already know, the critical engine is that engine which, when it fails, gives the highest  $V_{mc(a)}$ . Hence, we can expect a higher  $V_{mc(a)}$  when the critical engine fails than in a situation if the other engine were to fail - remember, the test pilot in determining his  $V_{mc(a)}$  was required to fail the critical engine.

### 3. CENTRE OF GRAVITY

$V_{mc(a)}$  is higher with an aft C of G as, in this configuration, it decreases pitch stability and the forces of the rudder are reduced because it shortens the moment arm and thus the turning moment, and therefore the greater the deflection required of the rudder to maintain directional control for a given airspeed. Naturally, if the aeroplane is loaded outside its C of G,  $V_{mc(a)}$  will be higher, (all other factors being equal).

Remember that an aeroplane yaws about its C of G and the following diagrams compare the yawing forces acting on the aeroplane with a forward and aft C of G. In diagram 15A, because the C of G is well forward, the correcting moment of the rudder is maximum. In diagram 15B, the C of G is well aft and as a result, the correcting moment of the rudder is minimum, so a much higher  $V_{mc(a)}$  will result.

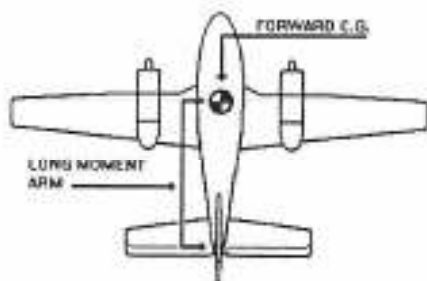


Diagram 15A

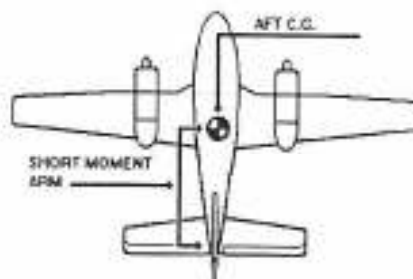


Diagram 15B

### 4. ALTITUDE

In aeroplanes with normally aspirated engines,  $V_{mc(a)}$  decreases with an increase in density altitude (or altitude), primarily because the output of the operating engine decreases, thus the minimum control speed for full power at altitude is less than at sea level. Whilst this lower  $V_{mc(a)}$  may be beneficial, it can also be dangerous as it often means it gets closer to the stall speed and, if  $V_{mc(a)}$  and stall speed are reached simultaneously, a spin is almost inevitable. Instructors who do not appreciate this lower  $V_{mc(a)}$ , and endeavour to demonstrate the sequence to trainees at what they assume to be a "safe" height, account for many stall/spin accidents (a "ROUGH" rule for the decrease in  $V_{mc(a)}$  is about 1 knot for each 1000 ft of altitude).

It is of paramount importance to remember, when demonstrating  $V_{mc(a)}$  at high altitudes, that the reduced  $V_{mc(a)}$  indicated airspeed may be lower than the one engine stall speed as the following diagram shows. The demonstration **MUST** cease at any indication of the stall, as otherwise a rapid deterioration in control will occur.

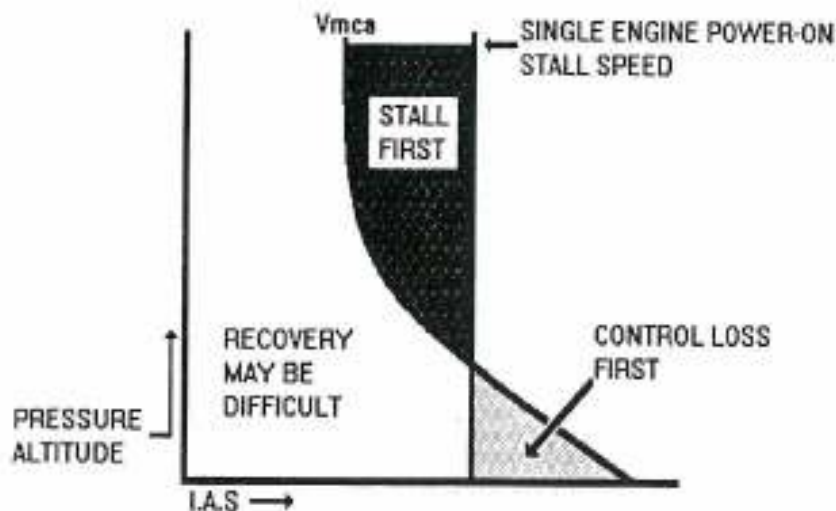


Diagram 16

## 5. AIR TEMPERATURE

Temperature affects density and therefore the power available. Also, there is the effect of humidity which has minimum aerodynamic effect but could appreciably affect piston engine power.

## 6. AEROPLANE CONFIGURATION

### a/ LANDING GEAR

Anything that increases the strength of the drag/thrust couple will normally lead to an increased  $V_{mc(a)}$ , however, with landing gear extended, there seems to be reasonable evidence that  $V_{mc(a)}$  reduces in the case of most light twins.

However, the type of landing gear fitted can also be a consideration of importance, e.g. folding forwards or rearwards instead of sideways may slightly change the C of G position during the operation of the landing gear. Any movement of the landing gear which leads to a rearwards movement of the C of G will increase  $V_{mc(a)}$ .



b/ FLAPS

Where an aeroplane has substantial drag flaps, a higher  $V_{mc(a)}$  than the published  $V_{mc(a)}$  should be anticipated, particularly when the flap is fully extended. This must be borne in mind in any "go around" where the aeroplane is in the landing configuration and is being flown in an asymmetric state. The rule to remember is that the more effective the flap or the more flap used, the higher will be the  $V_{mc(a)}$ . The reason for this higher  $V_{mc(a)}$  when flap is extended is that a greater rolling tendency occurs in situations when one engine is inoperative. It must be appreciated that behind a propeller which is producing thrust, the airflow is considerably greater than outside the slipstream. This increased airflow means more lift over that part of the wing affected by the slipstream, and hence, under asymmetric thrust conditions, a rolling tendency results. The amount by which the local lift increases depends on the local lift coefficient, which will be greater with flap extended than with flap retracted. It also depends on the thrust produced by the propeller and is therefore maximum at low airspeed and high power settings.

Unfortunately, manufacturers do not publish this critical  $V_{mc(a)}$  speed. One particular aeroplane which comes to mind has a published  $V_{mc(a)}$  of 89 knots - but with its full 60 degree of flap extended, the  $V_{mc(a)}$  increases to approximately 145 knots. Aeroplanes with 40 degrees of flap extended are quite likely to have the published  $V_{mc(a)}$  figure increased by 15 knots. It will vary however with every type of aeroplane and the actual  $V_{mc(a)}$  increase will depend on the type of flap, the amount of flap used, the engine power available, and whether the propeller is windmilling or feathered.

Many accidents can be attributed to pilots making an approach in the asymmetric configuration, finding themselves too high, extending full flap, and still having to execute an overshoot. Even though the airspeed was well above the published  $V_{mc(a)}$ , on selecting full take-off power on the good engine, they found they could not maintain control of the aeroplane. The reason - a much higher  $V_{mc(a)}$  than anticipated.

Remember the position of the flaps and their effectiveness can have a marked effect on the airflow over the wing and tail surfaces. As the effect varies between types, no general rule can be laid down. However, be aware of the effect of flap on  $V_{mc(a)}$  and the resulting uncontrollable rolling action which is likely to occur should full power need to be rapidly applied at relatively low airspeeds.

This is why, in a light twin engine aeroplane which is being flown in an asymmetric configuration, the decision and commitment to land normally occurs once you start your descent from circuit height and not, as many pilots believe, on final approach just prior to taking the final full flap setting at 300/400 feet.

c/ COWL FLAPS

Depending on the aerodynamic design of the intake entry and the positioning of the cowl flaps, the effect from the drag with the flaps open can be significant, and they should be closed on the inoperative engine as soon as possible - otherwise a slight increase in  $V_{mc(a)}$  should be anticipated, and this increase would depend on the actual type of cowl flaps.

d/ PROPELLER DRAG

If the propeller is allowed to continue windmilling, it still produces friction (30% of the power from an operating engine is used to overcome friction), and it is also acting as an air compressor.

The angle of attack of the blade to the relative airflow will produce a total reaction. This can be resolved into two forces - negative torque and negative thrust. The negative torque will cause the propeller to rotate i.e. windmill, stabilising at an RPM at which the negative torque balances the friction/compression forces - at this point, the negative thrust represents the extra drag penalty resulting from the windmilling. The main reason for feathering a propeller is to stop it windmilling, and thus reduce the large amount of asymmetric drag, besides possibly preventing further damage to the rotating engine parts. Naturally, with the propeller feathered, a lower  $V_{mc(a)}$  can be anticipated.

## 7. TURBULENCE AND WIND GUSTS

If turbulent and gusty conditions exist, this can affect the ability of the pilot to maintain directional control, and becomes an important factor when flying close to  $V_{mc(a)}$ . This is due to the fact that, during flight at  $V_{mc(a)}$ , the rudder most likely will be fully deflected, thus leaving no margin for any corrections in yaw which may be precipitated by air turbulence.

Therefore, during turbulent and gusty weather conditions, it will be particularly important to avoid flying at airspeeds close to  $V_{mc(a)}$ .

## 8. PILOT REACTION AND STRENGTH

Clearly, the faster the pilot's reaction to a sudden failure of one engine, the more easily and quickly he will regain control of the aeroplane. However, the physical strength and skill of the pilot will also be important factors in a critical situation such as flight at, or close to, the minimum control speed.

It is for this reason that it is extremely important for a pilot to adjust his seat during the flight preparation stage, to ensure that he is capable of obtaining full rudder travel. Skill developed from practice will also be important, in that a skilful pilot will more easily handle the additional workload brought about by sudden engine failure.



## 9. PILOT EXPERIENCE

Pilot experience is naturally a factor, however an experienced pilot who lacks knowledge and technique, can quite often be exposing himself to greater dangers than the well-trained in practice less experienced pilot.

## 10. WEIGHT

$V_{mc(a)}$  does not generally vary with aeroplane weight, but the danger lies where  $V_{mc(a)}$  happens to coincide with the stall speed. Thus at light weight, the difference between  $V_{mc(a)}$  and the stall speed will be greater than when the aeroplane is fully loaded. The stall with asymmetric power is to be avoided, particularly if it is approached with large rudder or aileron inputs. It is therefore necessary to ensure that any exercise to demonstrate the limits of asymmetric control is performed under conditions where a safe margin exists above the stall.

Again, the greater the all-up weight of the aeroplane, the greater the angle of attack for a given airspeed. Increased weight will create an increased induced drag and a reduced rate of acceleration, which are important factors when operating close to  $V_{mc(a)}$ .

## 11. ELECTRICAL LOADS AND AIRCONDITIONING

If the compressor for the airconditioning is mounted on the good engine, it is using power that could be converted into needed thrust for climb performance. Along the same lines, by reducing electrical loads, you can increase the thrust from the good engine. Remember, it takes power to produce electricity. In short, if you fail to obtain maximum power on the good engine, or fail to "clean-up" all drag producing items, the ability of the aeroplane to remain airborne on one engine may be seriously jeopardized.

## 12. DEGREE OF BANK APPLIED

The American FAR Part 23 which details the certification standards and requirements for the determination of  $V_{mc(a)}$ , **LIMITS** the amount of wing which can be lowered towards the operating engine to a **MAXIMUM** of 5 degrees. The reason for lowering the wing (or carrying the "dead" engine high) is that it permits a manufacturer to obtain a lower  $V_{mc(a)}$  than when the aeroplane is flown with the wings level.

The FAR imposes the 5 degree limitation on the bank as, if an aeroplane is banked in excess of 5 degrees towards the operating engine, an even lower  $V_{mc(a)}$  can be achieved.

$V_{mc(a)}$  can increase, with light twin engine aeroplanes, from 1 to 6 knots for each degree of bank away from the optimum bank angle, and varies with different aeroplane types.



One typical light twin engine aeroplane has a published  $V_{mc(a)}$  of 91 knots, but actual flight tests in an **INSTRUMENTED** aeroplane revealed that, with wings level, control of the aeroplane was lost at 117 knots - an increase of 26 knots! In the case of another aeroplane type, the published  $V_{mc(a)}$  is given as 84 knots but, with wings level, it increased by 10 knots.

When the manufacturers do their performance testing to establish the  $V_{mc(a)}$ , the aeroplanes used by the test pilots have precise instruments to determine the most efficient amount of bank angle within the 5 degree limit and, as a result, the lowest  $V_{mc(a)}$  can be obtained.

Unfortunately, such instruments are not available to the average pilot and, because the manufacturer is **NOT** required to disclose the actual bank angle used by the test pilot in establishing the  $V_{mc(a)}$  (nor is there a requirement for the manufacturer to provide **WINGS LEVEL  $V_{mc(a)}$**  - which would be most helpful to all pilots), it becomes an unknown figure. It can only be assumed that, in most cases, a 5 degree bank angle towards the operating engine was used.

The points to be remembered about  $V_{mc(a)}$  are :

1. It is important to know the manufacturer's **SEA LEVEL  $V_{mc(a)}$**
2.  $V_{mc(a)}$  **DECREASES** with altitude
3.  $V_{mc(a)}$  can be **HIGHER** when the aeroplane is flown **WINGS LEVEL**
4. If the airspeed is near  $V_{mc(a)}$  and an engine failure occurs - where possible, reduce the pitch attitude and trade height for airspeed
5. The published  $V_{mc(a)}$  is the  $V_{mc(a)}$  obtained by the test pilot at the time of the aeroplane's certification, when the aeroplane was required to be flown in a **SPECIFIED** configuration

The following Boeing 707 diagram has only been included for your interest, as there are many factors used in the determination of  $V_{mc(a)}$  for the large transport category aeroplanes which are not applicable to the light twin.

### EFFECT OF BANK ANGLE ON $V_{mc}$

B707-436

Reduced to ISA Sea Level Conditions

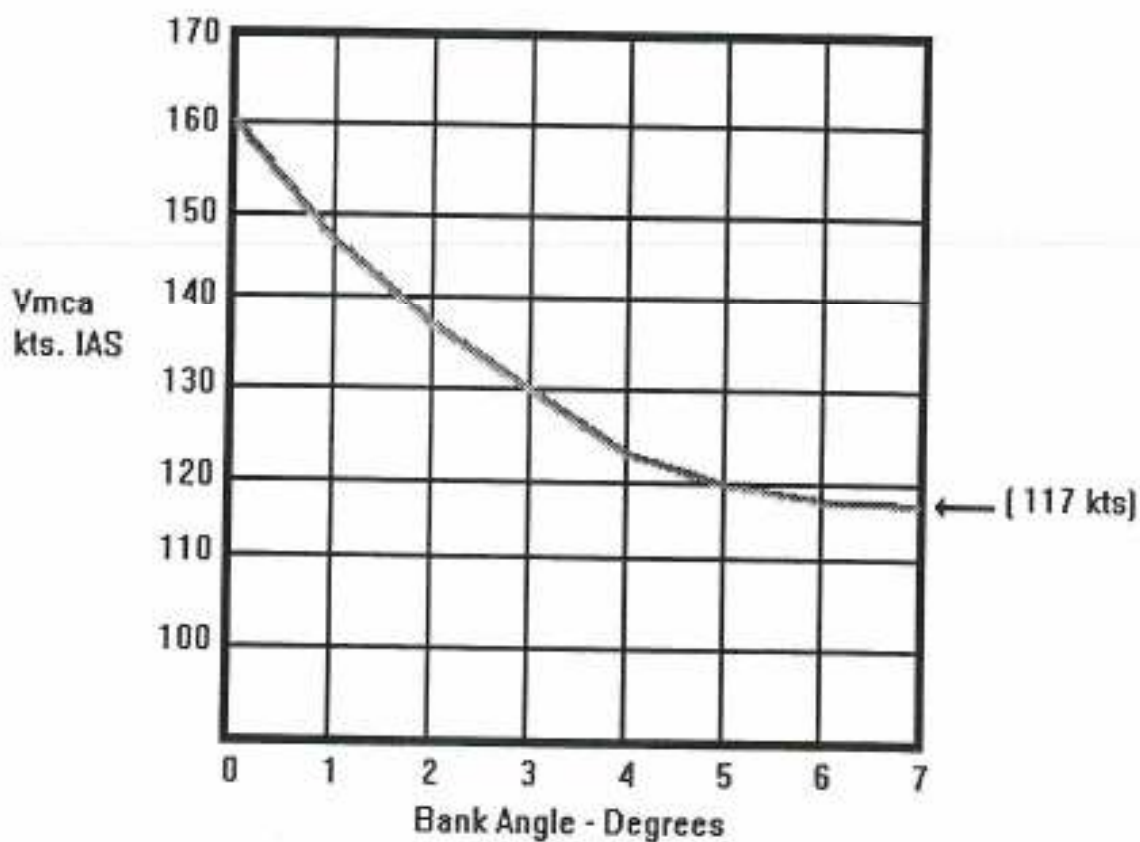


Diagram 17

### AERODYNAMIC SLIP

Many pilots are of the opinion that, in lowering the wing towards the operating engine to achieve the lowest  $V_{mc(a)}$ , the bank angle will also eliminate what is referred to as **AERODYNAMIC SLIP**.

Unfortunately, this doesn't happen. The fact is that  $V_{mc(a)}$  relates to **CONTROLLABILITY** and **DIRECTIONAL CONTROL** following an engine failure, whilst **AERODYNAMIC SLIP** relates to **CLIMB PERFORMANCE** with one engine inoperative. The only common denominator is that wing down towards the operating engine is used in both cases, so let us now explain aerodynamic slip.

The term **AERODYNAMIC SLIP** merely means that the direction of the relative airflow is not coinciding with the longitudinal axis of the aeroplane. This differs somewhat from the pilot's appreciation of the word "slip", as a pilot uses the term to describe a descending flight manoeuvre.

Some pilots are also under the impression that, in "balanced flight" i.e. with the wings level and the "ball" of the Turn and Balance Indicator in the centre, the aeroplane always flies straight through the air without slipping or skidding. That may be true in single engine aeroplanes, or in the twin engine aeroplane when equal power exists on both sides.

In an asymmetric situation however, the rules suddenly change. With the wings level, i.e. balanced flight with the ball of the Turn and Balance precisely centred and with one engine inoperative, the light twin engine aeroplane is actually side slipping or "crabbing" even though the aeroplane's heading is being maintained.

To prove this point, instructors, when endorsing pilots to twin engine aeroplanes, should consider taping a piece of string or yarn to the nose of the aeroplane, and try some single engine flying at  $V_y$  (best single engine rate of climb speed), initially with wings level balanced flight - this will prove that the aeroplane is crabbing through the air even though the aeroplane's heading is being maintained.

Following this demonstration, lower the wing towards the operating engine to permit the trainee to establish the actual amount of wing down required to eliminate the aerodynamic slip.

The aerodynamic slip (or crabbing) causes the relative wind on the inoperative engine side of the vertical fin to increase the asymmetric moment which follows failure of an engine. The large rudder input which is required to control the yaw tendency results in a "lateral" force on the vertical fin, and this is an "unbalanced" force. The result of all this is a loss of climb performance, even though the loss may be marginal.



The effect of this "lateral" force can be counteracted by lowering the wing on the side of the operating engine. There is a theory that, by allowing the aeroplane to accelerate sideways, the "lateral" force which results from the side slip will, at a certain airspeed, generate a rudder lift force which will eliminate the aerodynamic slip. Whilst this theory may or may not be correct, we do know that the elimination of aerodynamic slip is **NOT NECESSARY** at higher speeds such as during cruise.

Elimination of aerodynamic slip is an important consideration for the manufacturer when endeavouring to meet the "one engine inoperative" climb performance standards for certification. Even with the elimination of aerodynamic slip (which may only achieve as little as 20 fpm increase in climb performance), some aeroplane types still have to be weight limited to achieve the standard.

Now whilst **BOTH V<sub>mc(a)</sub>** and an aeroplane's **CLIMB** performance can be improved by applying bank towards the operative engine, unfortunately the results cannot be achieved simply by using the **SAME** bank angle.

Tests indicate that, to eliminate the aerodynamic slip and obtain the best **CLIMB PERFORMANCE** from the light twin engine aeroplane in the event of an engine failure, the amount of bank angle towards the operative engine can be as **LITTLE** as **2 degrees** and, whilst it can be higher, it is unlikely to reach 5 degrees.

The tests also revealed that, once the bank angle which eliminated the aerodynamic slip is **EXCEEDED**, the aeroplane's climb performance can **DETERIORATE RAPIDLY**, and that the amount of wing down for optimum climb performance in an engine failure situation **VARIES**, because it can be affected by many factors besides piloting ability.

As with establishing V<sub>mc(a)</sub>, when the manufacturers do their performance testing to demonstrate the aeroplane's capability of meeting the **CLIMB PERFORMANCE CERTIFICATION** requirements, the test pilot uses precise side slipping indicating instruments in his aeroplane to ensure zero side slip (or zero aerodynamic slip) is achieved. As a result, the best climb performance is obtained.

Pilots must appreciate that **BEFORE** a wing can be lowered following an engine failure, the aeroplane must **INITIALLY** be flown in **BALANCED FLIGHT** i.e. wings level and the ball of the Turn and Balance centred.

Pilots who attempt to lower a wing whilst the aeroplane is yawing only further deteriorate the aeroplane's performance due to the effect of aileron drag (i.e. the down aileron creates more drag than the up aileron).

Taking everything into consideration, if the test pilot's techniques and standard of flying cannot be duplicated, pilots may be better to **FORGET** about the elimination of aerodynamic slip as, in endeavouring to correct it, the climb performance too often will be seriously eroded instead of being improved. In other words, "wings level - balanced flight" could be the better of the two options!

Consider the following :

1. Whilst the elimination of aerodynamic slip may marginally increase the climb performance in the event of an engine failure, to obtain the performance, the aeroplane needs to be flown in similar conditions, and with the same degree of skill and precision as that displayed by the test pilot at the time of the aeroplane's original **CERTIFICATION** flying
2. The test pilot achieved his results in **SMOOTH** air conditions in an aeroplane equipped with **PRECISION TESTING INSTRUMENTS**, and in a **SIMULATED** emergency situation
3. If **MORE** than the optimum amount of bank is used, climb performance will be **DECREASED** rather than **INCREASED**
4. The **ACTUAL** amount of bank angle used by the test pilot is unknown
5. **CAN ANY PILOT, IN AN ACTUAL EMERGENCY SITUATION, BE EXPECTED TO ACCURATELY FLY OR RECOGNISE 1, 2, 3, 4 OR EVEN 5 DEGREES OF BANK ANGLE** - It is hard enough to recognise 20 degrees!
6. When one considers that the elimination of aerodynamic slip only requires such a **MINUTE** amount of bank to eliminate the unbalanced "lateral" force, this in itself suggests that the unbalanced lateral force is **NOT** a major consideration

If a pilot elects however to fly **WINGS LEVEL**, it must be remembered that :

1. **V<sub>mc(a)</sub>** could be much higher than the **PUBLISHED V<sub>mc(a)</sub>**
2. The **BEST SINGLE ENGINE RATE OF CLIMB SPEED (V<sub>yse</sub>)** is based on aerodynamic slip having been eliminated

When a pilot experiences an engine failure in a light twin engine aeroplane following take-off and continued flight is proposed, the **CORRECT** procedure is to :

1. **REGAIN DIRECTIONAL CONTROL** of the aeroplane
2. **FLY WINGS LEVEL - BALANCED FLIGHT**
3. **COMPLETE** the Engine Failure Check List procedures down to and including the feathering of the propeller, and the precision trimming of the aeroplane
4. **FLY V<sub>yse</sub>**
5. **THEN, AND ONLY THEN, CONSIDER** improving the aeroplane's performance by endeavouring to eliminate the aerodynamic slip - **BUT ONLY IF AN IMPROVEMENT IN PERFORMANCE IS ABSOLUTELY ESSENTIAL**



Let us now move on to some other definitions:

### V<sub>x</sub>

V<sub>x</sub> is the ALL engines operating best ANGLE of climb speed. Sometimes this speed can be less than V<sub>mc(a)</sub> for the aeroplane. Flown at V<sub>x</sub>, the aeroplane will gain the greatest height for a given distance of forward travel. This speed is used for obstacle clearance with all engines operating, however it will change when one engine is inoperative.

### V<sub>xse</sub>

V<sub>xse</sub> is the speed for best ANGLE of climb with ONE engine inoperative. It is used only to clear obstructions during an initial climb-out. It provides less engine cooling and requires more rudder deflection than V<sub>yse</sub>, besides being closer to the V<sub>mc(a)</sub> speed.

### V<sub>y</sub>

V<sub>y</sub> is the ALL engines operating best RATE of climb speed. This speed will give the maximum altitude for a given period of time with all engines operating. As with V<sub>x</sub>, this speed will also change when one engine is inoperative.

### V<sub>yse</sub>

This is the "published" indicated airspeed for best RATE of climb with ONE engine inoperative, and it is normally shown by a "blue line" on the airspeed indicator.

Actual V<sub>yse</sub> decreases with an increase in altitude, and as the weight of the aeroplane decreases, hence the "blue line" indication will not be correct for every situation - again in determining V<sub>yse</sub> the manufacturer's aeroplane was configured as follows :

1. Critical engine inoperative
2. Landing gear retracted
3. Propeller feathered
4. Wing flap in the most favourable (i.e. best lift/drag ratio) position
5. Aerodynamic slip eliminated
6. Cowl flaps as required for engine cooling

Flying your aeroplane at V<sub>yse</sub> does not necessarily guarantee a rate of climb. It will depend on how the aeroplane is configured, the condition of the engines, density altitude and piloting ability - just to name a few of the factors which can affect the performance capabilities of any aeroplane.

Vyse is important, however, as even though it may not necessarily guarantee you a rate of climb, it will make the most effective use of the power available, giving the least drag power ratio whether during climbing, holding, level flight or descending.

The only exception in usage would be when the best single engine angle of climb ( $V_{xse}$ ) has to be used when you are endeavouring to climb in an asymmetric configuration and are confronted by terrain obstacles.

In the event of engine failure following take-off, even with the propeller feathered and gear and flap retracted, if the airspeed is below  $V_{yse}$  and there is no height to trade, the only option is to descend straight ahead under control and accept the consequences. **DON'T TRY TO DO SOMETHING BEYOND YOUR CAPABILITIES OR THE CAPABILITIES OF YOUR AEROPLANE - DO SO, AND YOU ARE COURTING DISASTER!**

Pilots should also be aware of the dangers in attempting to climb or turn the aeroplane in level flight at speeds below  $V_{yse}$ , or  $V_{sse}$  (safe single engine airspeed with one engine inoperative). Loss of directional control or lift, or possibly both, can occur.

### **$V_{sse}$**

Many twin engine aeroplanes have a stalling speed which is close to (either above or below)  $V_{mc(a)}$ . This could lead to a dangerous situation if an engine failure was simulated when the aeroplane was operating at high power and close to  $V_{mc(a)}$ , where an uncontrollable yaw leading to a spin might easily result.

To avoid this possibility, the new term  $V_{sse}$  has recently been introduced. It is a guidance airspeed for pilots practising engine failure and is **defined** as follows :

"The recommended safe one engine inoperative speed which provides a safe margin above  $V_{mc(a)}$  to ensure the availability of control, and to guard against the possibility of entering a spin when one engine is suddenly stopped."

It should be borne in mind that  $V_{sse}$  can be affected by aeroplane and environmental conditions - and again, never forget that at altitude with the lower  $V_{mc(a)}$ , the aeroplane can stall before  $V_{mc(a)}$  is reached!

Sudden simulated engine failure below  $V_{sse}$  is not recommended by the manufacturer of currently built light twin engine aeroplanes. When the  $V_{sse}$  is not quoted in the Flight Manual or equivalent document (as will be the case of earlier manufactured aeroplanes) - the instructor, when demonstrating  $V_{mc(a)}$ , should approach this sequence in a cautious manner, giving it the respect it deserves.



### Vs

Vs is the stalling speed or the minimum steady flight speed at which the aeroplane is controllable.

Stall speeds for various configurations are established by trimming the aeroplane for approximately 1.4 times the stalling speed to be measured. The aeroplane speed is reduced in straight flight at a rate not exceeding 1 knot per second until the measured stall speed or minimum steady flight speed is reached.

The measured stall speed is the speed at which a large amplitude pitching or rolling motion, not immediately controllable, is encountered, when the manoeuvre described above is executed. An uncontrollable pitching motion of small amplitude associated with pre-stall buffeting does not necessarily indicate that the stalling speed has been reached.

Therefore, a simple stall speed definition is one which states, "the stall speed is the minimum speed in a stall, or minimum steady flight speed in the aeroplane configuration in which Vs is being used". Obviously, the variation to the aeroplane configuration for take-off or landing etc. becomes significant when establishing these stall speeds.

### Vs1

Vs1 is the stalling speed (or if no stalling speed is obtainable, the minimum steady flight speed at which the aeroplane is controllable) in knots CAS with the aeroplane in the configuration appropriate to the case under consideration.

The measured minimum steady flight speed is obtained, with the elevator control in the most rearward position possible when the manoeuvre described above is executed. This speed does not apply where the measured stalling speed occurs before the elevator control reaches its stop.

In determining Vs1 the aeroplane will be configured as follows:

1. Propellers in take-off position
2. The throttles closed or at not more than the power necessary for zero thrust at a speed not more than 110 percent of the stalling speed
3. Centre of Gravity in the most unfavourable position within the allowable range
4. The aeroplane in the configuration associated with the performance standard in which Vs1 is being used as a factor
5. Weight used when Vs1 is being used as a factor to determine compliance with a particular performance standard



V<sub>so</sub>

A stalling speed (or if no stalling speed is obtainable, the minimum steady flight speed at which the aeroplane is controllable), in knots CAS with the aeroplane in the landing configuration, with cowl flaps closed, propeller in the take-off position, Centre of Gravity in the most unfavourable position within the allowable range, and the throttles closed or at not more than the power necessary for zero thrust at a speed not more than 110% of the stalling speed.

V<sub>ref</sub>

The airspeed equal to the landing 50 ft position speed. This speed must not be less than 1.3 V<sub>so</sub> (i.e. 30 percent above V<sub>so</sub>) with flap in landing position and landing gear extended.

V<sub>1</sub>

Whilst V<sub>1</sub> has no significance for the light twins, pilots will hear the term and hence it has been included in these definitions.

V<sub>1</sub> is a take-off decision speed - it is the speed at which an engine failure is recognised. The distance to CONTINUE and climb to a height of 35 ft, or bring the aeroplane to a stop, is the SAME, and will not exceed the take-off field length distance available. The first action required "to stop or continue" is assumed to have been initiated at V<sub>1</sub>.

V<sub>r</sub>

The rotation speed (V<sub>r</sub>) shall not be less than V<sub>1</sub> or 1.05 V<sub>mc(a)</sub> (where V<sub>mc(a)</sub> is the minimum control speed - air), and must be compatible with V<sub>2</sub> (the take-off safety speed) and V<sub>mu</sub> (the speed at which the aeroplane can safely lift off the ground). It must be a speed such that if the aeroplane is rotated at maximum rate, then V<sub>lof</sub> (the speed that the aeroplane actually lifts off the ground) shall not be less than 1.1 V<sub>mu</sub> (all engines operating) or 1.05 V<sub>mu</sub> (one engine inoperative). As with V<sub>1</sub>, V<sub>r</sub> has no significance for the light twins.

V<sub>2</sub>

V<sub>2</sub> is a take-off safety speed, used in the larger transport category aeroplanes. This speed is the actual speed at 35 ft above the runway surface as demonstrated in flight during take-off with one engine inoperative. V<sub>2</sub> shall not be less than V<sub>2min</sub> or V<sub>r</sub> plus the speed increment gained in attaining a height of 35 ft, where V<sub>2min</sub> is the greater of 1.2 V<sub>s1</sub> or 1.1 V<sub>mc(a)</sub>. This definition relates to two engine aeroplanes and not the four engine. As with V<sub>1</sub> and V<sub>r</sub>, V<sub>2</sub> has no significance for the light twins.

### Vtoss

Take-off Safety Speed is the speed specified on the aeroplane take-off chart being the minimum speed to which an aeroplane must be accelerated in establishing the take-off distance required. The take-off safety speed is established for each flap setting for which take-off distance information is provided. The take-off safety speed shall be an airspeed not less than  $1.2 V_{s1}$  at which adequate control is available in the event of sudden complete engine failure during the climb following take-off. The aeroplane is configured with flap in the take-off position, landing gear extended, and engine(s) operating at maximum take-off power.

For aeroplanes not above 5700 kg in the **TRANSPORT CATEGORY**, the take-off safety airspeed "shall not be less than  $1.2 V_{s1}$  or less than  $1.1 V_{mc(a)}$ ".

The above requirements relate to the Australian standards. The American standards are slightly different inasmuch that the  $1.1 V_{mc(a)}$  applies in ALL cases.

Take-off safety speed does not mean the aeroplane has single engine climb performance.

### ZERO THRUST

During training in asymmetric flight, it is often undesirable to "shut the engine down" and feather the propeller.

Zero Thrust is the power which will simulate the reduction in drag experienced when the propeller is feathered. The setting, if not provided by the manufacturer, will be 10 to 12 inches of manifold pressure and about 2200 RPM, for most normal aspirated engines.

### CAS

Calibrated Airspeed is the indicated speed of an aeroplane, corrected for position error, and it assumes zero instrument error. Calibrated Airspeed is equal to True Airspeed in standard atmosphere at sea level.

### TAS (KTAS)

True Airspeed is the airspeed of an aeroplane relative to undisturbed air which is the CAS corrected for temperature, pressure and compressibility effects. (KTAS represents True Airspeed in knots).

### SINGLE ENGINE SERVICE CEILING

The single engine service ceiling is the maximum altitude at which an aeroplane will climb, at a rate of at least 50 ft per minute in smooth air, with one propeller feathered.

The single engine ceiling graph (if provided) should be used during flight planning to determine whether the aeroplane, as loaded, can maintain, in the event of an engine failure, the en route lowest safe altitude if operating IFR - or terrain clearance if operating VFR.



### ACCELERATE - STOP DISTANCE

This is the distance required to accelerate to lift-off speed and, assuming an engine failure at the instant that lift-off speed is attained, to bring the aeroplane to a full stop.

### ACCELERATE - GO DISTANCE

This is the distance required to accelerate to lift-off speed and, assuming an engine failure at the instant that lift-off speed is attained, to continue the take-off using the remaining engine to a height of 50 ft.

### ISA - INTERNATIONAL STANDARD ATMOSPHERE

The International Civil Aviation Organisation (ICAO) has established the standard conditions on which the scale of an altimeter can be based - this is known as the ICAO Standard Atmosphere - normally referred to as ISA.

It assumes that :

- (a) air is dry
- (b) that sea level pressure is 1013.2 hPa, and the temperature is 15 degrees centigrade
- (c) the temperature decreases at the rate of 1.98 degrees centigrade per 1000 ft up to 36,090 ft above which the temperature remains constant at minus 56.5 degrees centigrade

(refer to diagram 18 for the International Standard Atmosphere)

Since all aeroplane performance is compared and evaluated in the standard atmosphere environment, all of the aeroplane instrumentation is calibrated for standard atmosphere, thus certain corrections must be applied to the instrumentation as well as the aeroplane performance if the operating conditions do not fit the standard atmosphere. In order to properly account for the non-standard atmosphere, certain terms must be defined.

#### a/ PRESSURE ALTITUDE

Pressure Altitude is the altitude in the standard atmosphere corresponding to a particular pressure. The aeroplane altimeter is essentially a sensitive barometer, calibrated to indicate altitude in the standard atmosphere. If the altimeter is set for 1013.2 hPa (29.92 inches) against the subscale, the altitude indicated is the pressure altitude - the altitude in the standard atmosphere corresponding to the sensed pressure. Of course, this indicated pressure altitude may not be the actual height above sea level due to variations in temperature, lapse rate, atmospheric pressure, and possibly the errors in the sensed pressure. The more appropriate term for correlating aerodynamic performance in the non-standard atmosphere is :

b/ DENSITY ALTITUDE

Density altitude is the basis of all accurate airframe and engine performance calculations.

Density altitude in the standard atmosphere corresponds to a particular value of air density. It is derived from Pressure Altitude and Temperature. The Density Altitude Chart (diagram 19) illustrates how pressure altitude and temperature combine to produce a certain density altitude.

This Density Altitude Chart is quite standard in use, and is usually included in the performance sections of Flight Manuals or Aeroplane Operating Handbooks.

Aeroplane performance depends on air density, which directly affects lift, engine power, and propeller efficiency. As air density decreases, aeroplane take-off and landing performance decreases. Density altitude, therefore, provides a basis for relating air density to ISA, so that aeroplane performance can be more accurately determined.

When an aeroplane is taking off at a density altitude above ISA (i.e. density has decreased), it will still get airborne at the same INDICATED AIRSPEED as at sea level but, because of the lower density, the TRUE AIRSPEED (TAS) will be greater. To achieve this higher speed with the same engine power, a longer take-off run will be needed.

The effect of a high density altitude on power developed from the unsuper-charged engine is adverse, and less power will be available for take-off. (When taking off from a high density altitude airport, the engine will not even develop the power it is capable of at that altitude, unless the mixture is adjusted for the correct fuel-to-air ratio).

The following figures may be of interest :

- (a) The take-off distance is increased by 1 percent for every 100 ft of aerodrome **PRESSURE ALTITUDE** above sea level, and the landing distance by 1 percent for every 400 ft
- (b) The take-off distance is increased by 1 percent for every 1.4 degrees C that the **TEMPERATURE** is above standard for the aerodrome elevation

A high density altitude will also reduce the rate of climb, and the climb angle will be noticeably flatter, with a reduction in obstacle clearance ability immediately after take-off.



## THE INTERNATIONAL STANDARD ATMOSPHERE

HEIGHT ABOVE SEA LEVEL (1000'S ft)		TEMP. (C)	PRESS (mb)	RELATIVE DENSITY
70		-55	45	0.059
65	S	-56	57	0.075
	T			
60	R	-56	72	0.095
	A			
55	T	-56	92	0.121
	O			
50	S	-56	117	0.153
	P			
45	H	-56	148	0.194
	E			
40	R	-56	188	0.247
	E			
35		-54	239	0.311
	T			
30	R	-44	301	0.375
	O			
25	P	-34	377	0.449
	O			
20	S	-25	466	0.533
	P			
15	H	-15	572	0.629
	E			
10	R	-5	697	0.739
	E			
5		+5	843	0.862
SEA LEVEL		+15	1013	1.000

Diagram 18

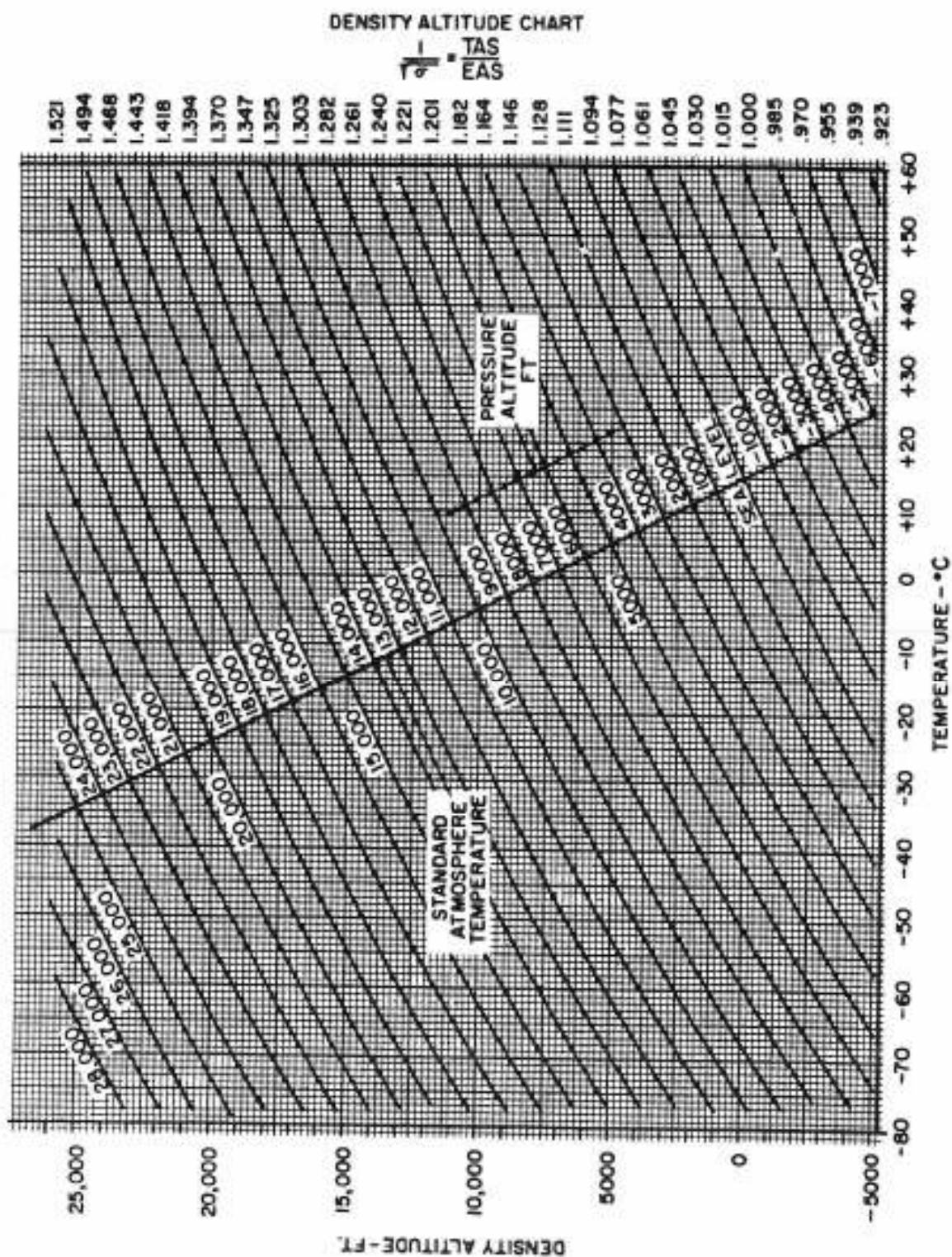


Diagram 19

If the Density Altitude Chart (diagram 19) is not available, the density altitude can still be determined using the following method :

Let us assume the QNH at the particular aerodrome is 1030, the elevation of the aerodrome is 2500 ft and the temperature is 27 degrees C.

- Step 1 - Set 1013.2 on the subscale and read the pressure altitude from the altimeter - the altimeter will read 1990 ft. If an altimeter was not available the following method can be used :

1030 minus 1013.2 equals 16.8 - say 17  
1 millibar equals 30 ft, hence 17 millibars equal 510 ft

Aerodrome height is 2500 ft - deduct 510 ft as QNH is higher - answer equals 1990 ft. (Rule is that if the QNH is MORE than 1013.2 - DEDUCT)

- Step 2 - Aerodrome temperature is 27 degrees C - based on ISA temperature being 15 degrees C at sea level and working on the fact that temperature decreases by 1.98 degrees C (use 2 degrees) per 1000 ft - this means temperature should have been 11 degrees C at 1990 ft (use pressure altitude and NOT aerodrome height) - however it was in fact 27 degrees - therefore, 27 minus 11 equals 16 degrees i.e. it was 16 degrees above ISA conditions

- Step 3 - Multiply by 120 every degree that temperature is above ISA i.e.  $120 \times 16 = 1920$  ft

- Step 4 - Add 1920 to 1990 = 3910, therefore density altitude is 3910 ft

**NOTE:** This 3910 ft density altitude does not take HUMIDITY into consideration, and a general rule is to add 500 ft to the density altitude to accommodate humidity. Hence, in this example, a pilot should accept the density altitude of 4410 ft for his calculations.



Let us now look at the effect of **HUMIDITY**.

Humidity is the amount of water vapour present in the air.

Up to now, we have only talked about **PRESSURE ALTITUDE** and **TEMPERATURE** as factors affecting density altitude - the reason being that the performance charts in Flight Manuals only take into account the **ELEVATION** and **TEMPERATURE** at the aerodrome.

They do not take into account the effect of **HUMIDITY** - when defining density altitude, this is done **ASSUMING THAT THE AIR IS DRY**. But air is rarely dry and, if water vapour is present, this produces the humidity. As temperatures increase so does the amount of water vapour a body of air is capable of holding.

Water vapour in the air **DECREASES** density and **INCREASES** the density altitude.

Diagram 20 shows the temperature correction for humidity. It is based on a wet bulb temperature adjusted by barometric pressure to provide a Temperature Correction Factor (TCF). The TCF is added to the dry bulb temperature (the temperature at the aerodrome) and this permits an accurate **DENSITY ALTITUDE** to be established as it now takes into consideration the combined effects of **HUMIDITY**, **PRESSURE ALTITUDE** and **TEMPERATURE**.

It should be remembered that, as well as increasing density altitude, humidity reduces the power output of the piston engine. In tropical areas, this loss of power can be as high as 10%. (Turbine engines do not suffer nearly as much from humidity as piston engines).

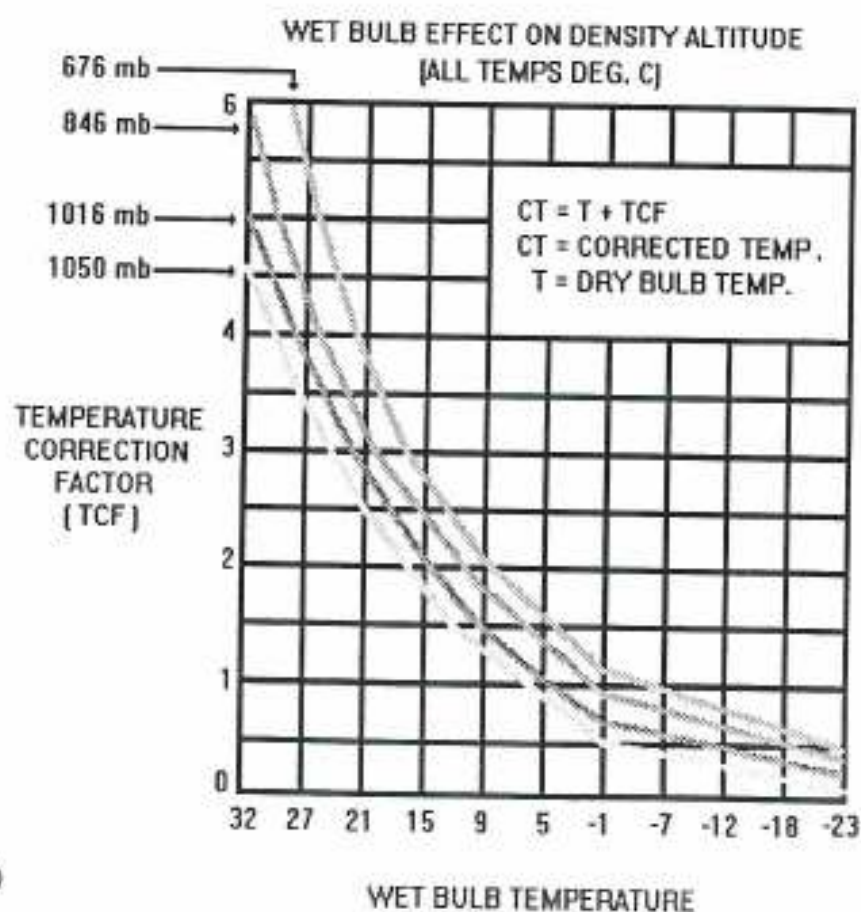


Diagram 20



Because **DENSITY** altitude will have a pronounced effect on aeroplane performance, pilots should :

1. Use the performance charts to calculate all operational values
2. Determine the **PRESSURE** altitude for the particular aerodrome by setting 1013.2 on the subscale of the altimeter and reading off the pressure altitude
3. Determine the **DENSITY** altitude of the aerodrome by adding 120 ft to the pressure altitude for each 1 degree C that the temperature is above standard if the Density Altitude Chart is not available
4. Make an adjustment for **HUMIDITY**, by applying the temperature correction, or by just an arbitrary increase of 500 ft to the density altitude

**ALWAYS REMEMBER THAT AIR DENSITY IS AN IMPORTANT FACTOR WHEN IT COMES TO AEROPLANE PERFORMANCE, AS IT DIRECTLY AFFECTS LIFT, ENGINE POWER, AND PROPELLER EFFICIENCY.**

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**PLEASE NOTE** Since printing this book :

1. CAO 101.22 has been cancelled
2. The American FAR Part 23.67 .027  $V_{so}^2$  single engine climb requirement for aeroplanes more than 6,000 lbs maximum weight and/or a  $V_{so}$  of more than 61 kts as detailed in this book, has now been replaced with a single engine climb gradient requirement of 1.5% (118.8 fpm). This new requirement only applies to aeroplanes certified after 1991, hence the information in this book is still relevant for the multi engine aeroplanes currently being used by flying training organizations. (FAR 23.67 will provide further information for those interested).

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## P E R F O R M A N C E

## PERFORMANCE

To understand the performance capabilities of light twin aeroplanes, it is first necessary to explain their design concepts and certification requirements.

In formal terms, light twin aeroplanes are those having a maximum take-off weight of 12,500 lbs or 5700 kgs. This arbitrary barrier separates the large transport category aeroplane from the normal, utility, and aerobatic aeroplane.

Designed in accordance with the fail safe concept, the large transport category aeroplanes can be said to represent the epitome of aerial safety. Simply speaking, "fail safe" implies that flight safety will not be unduly jeopardized should there be a failure of any one element (or in some cases, multiple elements) within any of the various systems comprising the complete aeroplane.

For example, wing structures have multiple load paths and essential items of equipment are duplicated.

To sustain this concept in terms of flight performance, it automatically requires at least two engines and at least two pilots. The certification requirements are such that, should one of the engines fail at any point from the beginning of the take-off to the completion of the landing, the flight can be safely terminated or continued. To achieve these standards, the aeroplane at times is required to operate at reduced weights.

Take-off performance is given to the pilot in the form of accelerate-stop, and accelerate-go distances, together with the appropriate decision speed (V1) and the take-off safety speed (V2). The aeroplane must be capable of making both an accelerate-stop and a continued take-off within the runway length available.

Take-off and en route flight paths are established, assuming engine failure at the most critical point, and the approach and landing segments are similarly treated. The weight of the aeroplane must be adjusted before take-off to accommodate the most critical of the above flight phases. The end result, of course, is a high level of safety.

It is not the intention to provide further discussion on the larger transport category aeroplanes, however, for those pilots interested, the certification requirements and the performance standards required are detailed in the American Federal Aviation Regulations (FAR's) Part 25 - similar standards apply in Australia.

The questions often asked are "why not design a light twin engine aeroplane to the larger transport aeroplane standards, and take full advantage of the extra safety, and why are light twin engine aeroplanes being built, certified and sold if incapable of maintaining height or climbing should an engine fail at a critical phase?"

The answer is that it can and has been done - and in fact, most corporate jets will meet this standard. A limited number of light twins could also meet the standard but, like everything else, it must be paid for and the price is high, not only in terms of initial purchase and subsequent maintenance costs, but also in relation to the operating economics. To realise the engine failure performance of the larger transport aeroplanes, the average light twin would be so payload limited it would be virtually unusable.



If light twins are to be operated in a realistic manner, a level of safety lower than that present in the large transport aeroplanes must be tolerated. This does not mean that manufacturers are prepared to compromise safety - provided you look after your equipment, the possibility of an engine failure during the critical take-off period is very remote and, if pilots understand the limitations and performance capabilities of these aeroplanes as well as their own limitations, there is no reason why the light twin aeroplane is not also a safe means of transport. After all, records prove that even the single engine aeroplane is a safe and reliable machine if correctly maintained and flown sensibly. This is not to say accidents will not happen - accidents are the cost of motion. But, with the correct training and the right attitude of the pilot in command, coupled with sound maintenance - many of those accidents currently attributed to one of those factors would be eliminated.

It is now time to look closely at the certification performance standards of the light twin aeroplane.

As most light twin aeroplanes are of American origin, our source of reference will be the American Certification Performance Standards which are detailed in the Federal Aviation Regulations Part 23 (FAR 23), and the Australian standards which are stated in the Civil Aviation Order 101.22 which is titled "Aircraft Certification Requirements - Aeroplanes in the Normal, Utility and Acrobatic Categories".

Although CAO 101.22 outlines Australian performance certification standards, it is interesting to note that it does not detail Design Standards i.e. if you wanted to build your own aeroplane from the word go, there is no independent Australian document you could refer to in order to determine the minimum standards for such airworthiness factors as controllability and manoeuvrability, trimming, stability, stalls and spins, or handling characteristics.

For this information, the CAO 101.22 refers to a definitive set of light aeroplane design standards as detailed in the American Federal Aviation Regulations Part 23 (FAR 23) titled "Airworthiness Standards - Normal, Utility and Aerobatic Category Aeroplanes".

It is also interesting to note that FAR 23.149 is where we find the definition of  $V_{mc(a)}$  - it appears in the section titled "Controllability and Manoeuvrability".

Before we examine the difference between the American and Australian Certification Standards, it must be emphasised and accepted by all pilots that, in the case of the light twin aeroplane, FAR 23 and CAO 101.22 which stipulate the various certification standards, are **CERTIFICATION PERFORMANCE STANDARDS ONLY**, and the figures and information produced can be somewhat misleading and artificial when it comes to providing reliable information to the pilot. Unfortunately some of this "misleading" information can appear in the Pilot's Operating Handling Notes and in the aeroplane's Flight Manual. This is why it is essential for all pilots to fully understand what the certification performance standards are all about.



**CERTIFICATION STANDARDS** are the minimum acceptable performance standards an aeroplane is required to demonstrate before it can be granted a Certificate of Airworthiness. What we are saying is that the aeroplane we fly will not necessarily meet the same performance standards achieved by the test pilot in his brand new aeroplane, with new engines, new propellers, being flown in still air conditions, during daytime, and at ISA temperatures - an entirely different situation to what happens in real life.

As already stated the American standards are covered by FAR 23 and the Australian by CAO 101.22 - pilots have no control over these standards. Whilst CAO 101.22 relates to the **CERTIFICATION** standards in Australia, in Australia there are also additional **OPERATIONAL** standards and these are detailed in CAO 20.7.4. The **OPERATIONAL** standards however have **NOTHING** to do with the **CERTIFICATION** of an aeroplane. They are the minimum operational performance standards a **PILOT** must ensure the aeroplane can meet, given the present aeroplane weight and the ambient conditions.

The first important point to make is that neither FAR 23, nor CAO 101.22 has **ANY** requirement for the light twin aeroplane to demonstrate continued one engine inoperative climb capability immediately following take-off and during the initial climb - the most critical phase of flight for a light twin, hence there is a period after lift-off where, should an engine fail, an accident could well occur.

For all light twin aeroplanes, the take-off and initial climb are considered to be an all engine operating manoeuvre, and Flight Manual distances and take-off climb data are determined on this basis. V1, V2 and Vr speeds which are used for the large transport category aeroplanes, have no meaning for the light twins. The take-off safety speed which is supplied provides (theoretically) that pitch control of the aeroplane is available in the event of engine failure following rotation. Whilst the **TAKE-OFF DISTANCE** charts shown in Australian Flight Manuals are an all engine distance from a standing start to clear a 50 ft obstacle, multiplied by a safety factor which is between 1.15% and 1.25%, the **AMERICAN TAKE-OFF DISTANCES** which can also be found in some Aircraft Flight Manuals, in Manufacturer's Data Manuals and Pilot's Operating Handbooks, (usually presented in tabulated form), **ARE NOT FACTORED AT ALL.**

To establish a take-off **DISTANCE** the test pilot positions the aeroplane at the threshold of the runway, with the mixtures adjusted to optimum setting, the brakes locked, and maximum power - then releases the brakes - a somewhat different take-off technique to that normally used! And remember that the test pilot is flying a new aeroplane specially prepared for these certification test flights.

All aeroplanes deteriorate to some extent after they have been in service for a time - engines may no longer develop full power, propellers often deteriorate, and doors and panels might not fit as well as they did when the aeroplane was new - hence the performance figures achieved by the test pilot could well be incorrect if related to your aeroplane, due to its condition and the fact that you are not necessarily using the same techniques as those used by the test pilot.

We shall now consider what the performance certification requirements are for these light twin aeroplanes. Since we are talking about aeroplanes below 5700 kgs (12500 lbs) which are normally manufactured in the USA, our reference sources will be the certification performance requirements of FAR 23 and CAO 101.22. After comparing these American and Australian **CERTIFICATION** standards, we will then look at the additional **OPERATIONAL** requirements detailed in CAO 20.7.4 which also apply to Australian registered aeroplanes.

**FAR 23 specifies performance requirements for :**

- Take-off Distance
- Climb: All Engines
- Climb: One Engine Inoperative
- Landing Distance
- Baulked Landing Climb: All Engines

**CAO 101.22 specifies performance requirements for :**

- Take-off Distance
- Take-Off Climb: All Engines
- En-route Climb: All Engines
- En-route Climb: One Engine Inoperative
- Baulked Landing Climb: All Engines
- Landing Distance

It can be seen that nowhere is there any requirement for the aeroplane to have climb capability following an engine failure just after lift-off - the most critical phase of flight for the light twin. As already stated, the take-off and initial climb are considered to be an all engine operating manoeuvre and the Flight Manual distance and take-off climb data are determined on this basis.

Let us now examine the certification performance requirements in more detail.

### **NORMAL, UTILITY, AEROBATIC (FAR 23)**

All FAR 23 performance is based on still air, ISA conditions, and at 80% relative humidity. The following general tolerances are allowed :

Weight	+5% to -10%
Critical items affected by weight	+5% to - 1%
Centre of Gravity	+7% total travel

### **TAKE-OFF DISTANCE (FAR 23)**

The distance required to take-off and climb over a 50 ft obstacle must be determined with:

- Engines operating within approved limits
- Cowl flaps in the normal take-off position
- Lift-off speed must not be less than  $V_{mc(a)}$  and - the aeroplane must reach a speed at 50 ft of not less than the higher of :

- (1)  $1.1 V_{mc(a)}$  or
- (2)  $1.3 V_{s1}$ , or any lesser speed not less than  $V_x + 4$  kts, that is shown to be safe under all conditions

\*  $V_{s1}$  is the power idle stall speed for the take-off configuration

\*  $V_x$  is the best angle of climb speed all engines operating

### **CLIMB: ALL ENGINES OPERATING (FAR 23)**

Each aeroplane must have a steady rate of climb at sea level of at least 300 fpm and a steady angle of climb of at least 1 in 12 (8.3%) with :

- Not more than maximum continuous power on each engine
- Landing gear retracted
- Flap in take-off position
- Cowl flaps as required for cooling



### CLIMB: ONE ENGINE OPERATING (FAR 23)

Far 23 stipulates that the **PARAMETERS** and **CONDITIONS** which shall apply for the **ONE ENGINE INOPERATIVE CLIMB** certification flight test are :

- Flight test to be completed at 5000 ft
- ISA conditions
- Still air conditions
- Critical engine stopped and its propeller feathered
- Not more than maximum continuous power on remaining engine
- Gear up with flap in most favourable (best lift/drag) position
- Cowl flaps as required for cooling
- Aeroplane at maximum take-off weight
- Aerodynamic slip can be eliminated - (this is achieved by the test pilot's use of precision side slip measuring equipment which, as we know, is not installed in the production aeroplane - unfortunately, the actual optimum bank angle used is not normally provided)

FAR 23 also states that the **ONE ENGINE INOPERATIVE CLIMB** performance (or the single engine climb performance) required for the particular aeroplane, will be assessed against the figure obtained using the formula **RATE OF CLIMB (ROC) = 0.027 V<sub>so</sub> squared**, where V<sub>so</sub> is the power idle stall speed in the landing configuration or, to be more specific, V<sub>so</sub> (in knots CAS) is the stalling speed, if obtainable, or the minimum steady flight speed at which the aeroplane is controllable with :

- Full flap and gear down
- Propeller in the take-off position
- Cowl flaps closed
- Centre of Gravity in the most unfavourable position within the allowable range
- Weight used when V<sub>so</sub> is being used as a factor to determine compliance with a particular performance standard
- For reciprocating engine powered aeroplanes - engines idling with throttles closed or at not more than the power necessary for zero thrust at a speed not more than 10 per cent above the stalling speed,

or

in the case of turbine engine powered aeroplanes - the propulsive thrust shall not be greater than zero at the stalling speed, or, if the resultant thrust has no appreciable effect on the stalling speed, with engines idling and throttles closed



In applying the  $0.027 V_{so}^2$  formula for the **ONE ENGINE INOPERATIVE CLIMB**, FAR 23 divides the light twin engine aeroplane into two weight classes, split at 6000 lbs. (The **CONDITIONS** and **PARAMETERS**, as listed on the previous page, to apply in all cases).

1. For aeroplanes with a maximum weight of **6000 lbs or LESS** :
  - (a) If the  $V_{so}$  is **MORE** than 61 kts, the manufacturer must be able to **DEMONSTRATE** that the aeroplane is capable of maintaining a steady rate of climb of at least  $0.027 V_{so}^2$ , or
  - (b) If  $V_{so}$  is **EQUAL** to or **LESS** than 61 kts, the manufacturer is only required to **DETERMINE** whether the aeroplane can or cannot achieve a steady rate of climb - note that there is no requirement for a positive rate of climb - or to put it another way, there is no minimum climb rate required to be **DEMONSTRATED**.

2. For aeroplanes **ABOVE 6000 lbs** up to and including 12500 lbs :

The manufacturer must be able to **DEMONSTRATE** the aeroplane is capable of maintaining a steady rate of climb of at least  $0.027 V_{so}^2$ , irrespective of its stalling speed.

As can be seen, with the American certification standards, only those twins that weigh more than 6000 lbs or have a  $V_{so}$  higher than 61 kts are required to **DEMONSTRATE** a single engine climb performance for certification.

#### **LANDING DISTANCE (FAR 23)**

The distance necessary to land and stop from 50 ft must be determined from the following approach condition :

- a steady gliding approach with a CAS of at least  $1.3 V_{s1}$  must be maintained down to the 50 ft height

#### **BAULKED LANDING CLIMB: ALL ENGINES (FAR 23)**

The aeroplane must be able to maintain a steady angle of climb at sea level of at least 1 in 30 (3.3%) with :

- take-off power
- gear and flap down

That completes the American certification performance requirements as outlined in FAR 23.

Let us now look at CAO 101.22 :

### NORMAL, UTILITY, ACROBATIC (CAO 101.22)

As with the FAR 23 certification performance requirements, the performance is based on still air and ISA conditions.

Once again, we make the point that pilots must realise the results obtained during these performance tests are for **AEROPLANE CERTIFICATION** and bear little in the way of providing performance information for a pilot, as all these performance figures were recorded with a factory fresh aeroplane, fitted with new engines, and flown by a highly skilled test pilot, flying his aeroplane precisely, and in ideal weather conditions.

### TAKE-OFF DISTANCE (CAO 101.22)

The take-off distance shall be established on a hard dry sealed runway surface and shall be the distance required to reach a screen height of 50 ft above the runway from a standing start with :

- all engines within maximum take-off power limitations
- the aeroplane reaching 50 ft at not less than  $V_{\text{toss}}^*$
- gear down and take-off flap set
- cowl flaps in the normal take-off position

\*  $V_{\text{toss}}$  (take-off safety speed) shall be an airspeed not less than  $1.2 V_{\text{s1}}$  at which adequate control is available in the event of a sudden complete engine failure during the climb following take-off

The take-off distance obtained will be multiplied by the following factors (the factored distances are used when compiling the Australian Take-off Performance Charts) :

- 1.15 for aeroplanes with a MTOW of 2000 kg (4409 lbs) or less
- 1.25 for aeroplanes with a MTOW of 4500 kg (9921 lbs) or more
- with linear interpolation between the two

Note that the CAO 101.22 take-off distance definition differs from the FAR 23 equivalent, in the area of the 50 ft airspeed - there is no mention of  $1.1 V_{\text{mc(a)}}$ , (the  $1.1 V_{\text{mc(a)}}$  only becomes a consideration in the establishment of  $V_{\text{toss}}$  with aeroplanes below 5700 kg in the transport category). The American standards call for no factoring of the take-off distance, and pilots should keep this in mind when seeking to meet the operational performance requirements laid down in CAO 20.7.4. for take-off distance.

Whilst there are differences in the Australian and American standards, no conflict exists, as in Australia the imported American aeroplanes must satisfy BOTH the American requirements (FAR 23) and the additional Australian requirements (CAO 101.22).

### A WARNING ABOUT $V_{toss}$ !

In establishing  $V_{toss}$ , the light twin engine aeroplane is considered as a **SINGLE ENGINE** aeroplane.  $V_{toss}$ , by definition, is "the take-off safety speed, not less than  $1.2 V_{s1}$ , at which adequate control is available in the event of sudden engine failure during the climb following take-off. The aeroplane is configured with the flap in the take-off position, landing gear extended, and engine(s) operating at maximum take-off power". The  $V_{toss}$  **IS ESTABLISHED BY THE TEST PILOT - THERE IS NO FACTORING** for such things as the 7 second pilot reaction time (explained later) - piloting skill - aeroplane condition - environmental considerations - problems from an engine failure in a light twin engine aeroplane - **OR  $V_{mc(a)}$** . With regards  $V_{mc(a)}$ , just take the Twin Commanche - published  $V_{mc(a)}$  is 80 knots and  $V_{toss}$ , according to CAO 101.22, is also 80 knots.

Should an engine fail in a light twin aeroplane at take-off safety speed with the gear extended and a windmilling propeller,  $V_{toss}$  has no significance and must never be considered as a speed which will provide the "adequate control" as suggested by the definition of  $V_{toss}$ .

It's not that the definition of  $V_{toss}$  is wrong - it is just that many pilots do not appreciate or understand that **CERTIFICATION** information often appears in the Pilot's Handling Notes without a full explanation of its true meaning and, unless the true meaning is understood by a pilot, safety standards are jeopardized.

### TAKE-OFF CLIMB: ALL ENGINES OPERATING (CAO 101.22)

The gradient of climb of the take-off shall not be less than 6% under the following conditions :

- Gross Weight :
  - (i) at sea level ISA - equal to maximum take-off weight, and
  - (ii) at all other pressure altitudes and temperatures - equal to the gross weight being established as the maximum for take-off at the particular altitude and ambient temperature
- airspeed equal to the take-off safety speed ( $V_{toss}$ )
- wing flap in the take-off position
- landing gear extended
- all engines operating within maximum take-off power limitations



### **EN ROUTE CLIMB: ALL ENGINES OPERATING (CAO 101.22)**

The en route gradient of climb shall not be less than 4% under the following conditions :

- maximum take-off weight
- all pressure altitudes up to 5000 ft
- ambient temperature equal to ISA + 10 degrees C
- airspeed not less than 1.2 Vs1
- all engines operating within maximum continuous power limitations

### **EN ROUTE CLIMB: ONE ENGINE INOPERATIVE (MULTI-ENGINE AEROPLANES) (CAO 101.22)**

1. For VFR operations the en route gradient of climb shall not be less than 0% under the following conditions :

- maximum take-off weight
- all pressure altitudes up to 5000 ft
- ambient temperature equal to ISA + 10 degrees C
- airspeed not less than 1.2 Vs1
- critical engine inoperative and its propeller feathered
- remaining engine(s) operating within maximum continuous power limitations

2. For IFR operations a gross weight, not greater than the maximum take-off weight, shall be established such that the steady gradient climb shall not be less than 0.5% under the following conditions :

- all pressure altitudes up to 5000 ft
- ambient temperature equal to ISA + 10 degrees C
- airspeed not less than 1.2 Vs1
- critical engine inoperative and its propeller feathered
- remaining engine(s) operating within maximum continuous power limitations

In absolute terms, the above performance levels are not high - for example, a 0.5% gradient represents a rate of climb for the average light twin between 40 and 60 fpm - even so, there are quite a number of modern aeroplanes which need to be weight limited to achieve even this performance. Since 50 ft per minute (fpm) is usually the specified rate of climb for the single engine service ceiling, the 0.5% gradient requirements, in a way, ensure an IFR service ceiling of at least 5000 ft at ISA + 10 degrees. But again, these are the results achieved by the test pilot in his "factory fresh" aeroplane.

It will be interesting now to pause and summarise the differences between the American FAR 23 and the Australian CAO 101.22 **EN ROUTE CLIMB: ONE ENGINE INOPERATIVE** requirements.

1. Whilst both the American and Australian performance levels must be demonstrated at a pressure altitude of 5000 ft, the Americans stipulate an outside air temperature of ISA (5 degrees C at 5000 ft) - the Australian requirement is ISA + 10 degrees (15 degrees C at 5000 ft). This is to account for the warmer Australian operating conditions.
2. **FAR 23 CLIMB: ONE ENGINE INOPERATIVE** - applies to all aeroplanes VFR or IFR. **CAO 101.22 EN ROUTE CLIMB: ONE ENGINE INOPERATIVE** has separate requirements for VFR and IFR.

It can be seen that there is nothing in the Australian or American regulations governing the certification of light twin engine aeroplanes which says they must be able to fly (maintain height or climb) whilst in the **TAKE-OFF** configuration, and with one engine inoperative. With regard to performance, but not controllability, in the take-off or landing configuration the light twin engine aeroplane is considered to be merely a single engine aeroplane with the power divided into two packages. This must be clearly understood.

Unlike transport aeroplanes where positive one engine inoperative climb performance is always available, the light twin is required to demonstrate engine out performance only in the en route configuration. Take-off, approach and landing are not considered. The take-off and initial climb are thus considered to be all-engines operating manoeuvres, and the Flight Manual take-off distance and take-off climb data are scheduled on this basis.

#### **BAULKED LANDING CLIMB: ALL ENGINES (CAO 101.22)**

The steady gradient of climb shall not be less than 2% under the following conditions :

- maximum landing weight
- pressure altitude of the landing surface, ISA + 22.7 degrees C
- airspeed equal to 1.3 V<sub>so</sub>
- wing flap in the landing position
- all engines operating within maximum take-off power limits

### LANDING DISTANCE (CAO 101.22)

The distance necessary to land and stop from 50 ft must be determined following a steady approach to the 50 ft height, and the airspeed must not be less than 1.3  $V_{so}$ . The landing surface shall be a hard dry sealed runway.

The landing must be made without excessive vertical acceleration and without tendency to bounce, nose over or ground loop.

In establishing the landing distance, ground idle propeller settings may be used provided that:

- both ground idle and reverse propeller pitch settings are available and selection of ground idle pitch is made only after touchdown;
- for multi-engine aeroplanes, the ground handling characteristics with asymmetric reverse thrust have been determined to be safe

Like take-off distances, landing distances are also multiplied by the following factors:

- 1.15 for aeroplanes having a MTOW of 2000 kg (4409 lbs) or less
- 1.43 for aeroplanes having a MTOW of 4500 kg (9921 lbs) or more
- with linear interpolation between the two

Imported aeroplanes flying in Australia must satisfy both the FAR 23 and CAO 101.22 specifications.

Let's now look at the additional **OPERATIONAL** Performance Requirements.

### OPERATIONAL PERFORMANCE REQUIREMENTS (CAO 20.7.4)

In Australia, besides the Certification Performance Requirements, there are also Operational Performance Requirements.

The Operational Performance Requirements refer to the minimum performance standards a pilot must ensure the aeroplane can meet in order to be safely operated. These requirements are stated in CAO 20.7.4 titled "Aeroplane Weight and Performance Limitations - PVT, AWK (excluding AG), and CHTR".



Apart from take-off and landing weight limitations, **CAO 20.7.4** specifies performance requirements for :

- Take-off Distance Required
- Take-off Climb: All Engines
- En Route Climb: One Engine Inoperative
- Landing Climb Performance: All Engines
- Landing Distance Required

#### **TAKE-OFF DISTANCE REQUIRED (CAO 20.7.4)**

The take-off distance required shall be the distance to accelerate from a standing start with all engines operating and to achieve  $V_{\text{toss}}$  at a height of 50 ft above the take-off surface, multiplied by the following factors :

- 1.15 for aeroplanes with a MTOW of 2000 kg (4409 lbs) or less
- 1.25 for aeroplanes with a MTOW of 3500 kg (7761 lbs) or more
- with linear interpolation between the two

The pilot ensures compliance with these requirements by using his "P" (Performance) charts in the Flight Manual which already have the multiplication factors built into them.

#### **TAKE-OFF CLIMB: ALL ENGINES (CAO 20.7.4)**

In the take-off configuration with landing gear extended, an aeroplane shall have the ability to achieve a climb gradient of 6% at  $V_{\text{toss}}$ , without ground effect, and with all engines operating at take-off power.

Pilots will be familiar with the climb weight limit line incorporated in some take-off P-Charts to ensure compliance with this 6% take-off gradient. Note once again the recurring design philosophy theme, in that there is no provision made for any engine-out performance whilst in the take-off configuration.

#### **EN ROUTE CLIMB: ONE ENGINE INOPERATIVE (CAO 20.7.4)**

IFR Charter and Aerial Work aeroplanes must have the ability to climb at a gradient of 1% at all heights up to 5000 ft ISA, with :

- propeller of critical engine feathered
- gear and flap up
- maximum continuous power on remaining engine(s)
- airspeed not less than 1.2  $V_s$

VFR and all other aeroplanes, i.e. private IFR aeroplanes, must have the ability to maintain height (i.e. 0% climb gradient) at all heights up to 5000 ft ISA in the same configuration as outlined above.

CAO 101.22 states that the Flight Manual "shall contain the performance information necessary for observance of the operational requirements specified in Civil Aviation Orders". We expect then that the Flight Manual should contain any weight limitations etc. which will ensure compliance with the **OPERATIONAL** requirements for the en route climb.

This is not so for the IFR case. The Flight Manual is geared around the certification performance standard of 0.5% at 5000 ft ISA + 10. We are not supplied with any information that will ensure observance of the 1% operational requirement at 5000 ft ISA. True, the extra drop in temperature of 10 degrees will be beneficial, but this only spells about 20 to 30 fpm extra climb rate or, in gradient form, about 0.25%. The best the pilot can hope for, if he follows the IFR MTOW stated in the Flight Manual, is to achieve around a 0.75% gradient, which falls short of the operational requirement.

#### LANDING CLIMB PERFORMANCE (CAO 20.7.4)

In the landing configuration with all engines operating at take-off power, an aeroplane shall have the ability to climb at a gradient of 3.2% in standard atmospheric conditions at a speed not exceeding 1.3 Vs.

#### LANDING DISTANCE REQUIRED (CAO 20.7.4)

The landing distance required is the distance from 50 ft to a full stop, following an approach to the 50 ft height at an airspeed not less than 1.3 Vs, multiplied by the following factors :

- 1.15 for aeroplanes with a MTOW of 2000 kg (4409 lbs) or less
- 1.43 for aeroplanes with a MTOW of 4500 kg (9921 lbs) or more
- with linear interpolation between the two

So ends our explanation and comparison of the American and Australian Certification and Operational Requirements as detailed in FAR 23, CAO 101.22 and CAO 20.7.4.

#### **REMEMBER :**

1. Now that the Australian Civil Aviation Authority is accepting foreign Flight Manuals and Manufacturer's Data Manuals that include **TAKE-OFF** and **LANDING DISTANCES**, the figures provided (often in tabulated format) could be **UNFACTORED**.
2. The aeroplane used at the time of its certification, besides being brand new, was also being flown by a highly qualified test pilot in ideal conditions and the results were not factored for such things as pilot experience and reaction time, above ISA temperatures, turbulence, environmental considerations such as night and weather, or aeroplane condition - factors which must erode, to some degree, the results obtained by the test pilot.



This is why, throughout this book, it has been stressed constantly that the performance figures obtained by the test pilot during the certification of the aeroplane, may not necessarily be achievable in the aeroplane you will be flying, and that some of the certification performance data which appear in Flight Manuals, the Manufacturer's Data Manuals and the Pilot's Handling Notes, whilst technically correct, can in fact be misleading and could even contribute to an accident if used in a marginal situation. Just two examples :

Consider the **TAKE-OFF** distances - in achieving his figures, the test pilot, using all available runway, and with brakes locked, mixture set to optimum, engines operating at take-off power, then released the brakes - the results achieved are the take-off distances which appear in the Flight Manual, unfactored in the American manuals but with a factor applied in the case of the Australian take-off charts. In fairness to the American figures however, whilst they may not be factored, their certification requirements for establishing take-off distances are more conservative than those used by the Australian authorities, and this no doubt is one of the reasons why the Australian take-off distances are factored.

The point being made is that the actual take-off technique used by the test pilot is different from the one pilots normally use which, as we know, is to smoothly open the throttle. Smoothly opening the throttle however can result in an additional take-off distance in the vicinity of 300 ft, and this figure will increase as the density altitude increases.

**PILOT REACTION TIME** is yet another consideration which is not taken into account, and yet it is a very important factor.

Medical experts (who try to figure out why pilots do the things they do) have identified four stages in an actual engine failure emergency.

The first stage lasts about three seconds - during this period, the pilot experiences either an unexpected reaction to a controlled input, or gets no reaction at all - this quite understandably is referred to as **CONFUSION TIME**.

It takes two more seconds for the pilot to realise that the cause of the problem is that the engine has failed - this is the **RECOGNITION PHASE**. For one more second, the pilot reaction is "no, this can't be happening to me" - this is called the **DENIAL PHASE**.

Therefore it will be seven seconds before the pilot begins to take the appropriate action (that is, if control of the aeroplane has not already been lost).

There are many other examples which could provide further justification to show that there is a need to exercise a degree of discretion when using information which appears in the various operational manuals.

Let us now look at what actually happens to the climb performance of these light twin engine aeroplanes when one engine is inoperative.



Whilst anyone could be excused for thinking that when an engine fails in a light twin, it will only result in a 50% loss of performance - this unfortunately is not the case. The fact is that the light twin engine aeroplane actually loses anything from 78% to 90% of its climb performance at sea level, which means an engine failure following take-off can create a dangerous situation.

Even in the turboprops and business jets, the performance loss ranges between approx. 68% to 82%, however such a loss is not nearly as critical with these aeroplanes as it is with the light twin, simply because in nearly every case, the business jets and the turboprop aeroplanes have a much better all engine rate of climb. For example, even though the Falcon 10 incurs a 75% loss, it is still capable of maintaining a single engine climb rate of 800 fpm - this is because its all engine climb performance is 3,300 fpm.

In addition to their better all engine rate of climb, many turboprop aeroplanes and most turbojets are certified to the requirements of FAR 25 which details the certification standards for transport category aeroplanes and aeroplanes over 12,500 lbs (or 5,700 kgs), and as such, the regulations required these aeroplanes to be capable of **CONTINUED** take-off capability with one engine inoperative.

Why the performance loss with these light twins is greater than 50% with the failure of one engine can be best explained as follows.

Climb performance is a function of excess thrust horsepower (or excess thrust in the case of the turbojet), and is determined using the following formula :

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

where R/C is the rate of climb, ehp is the thrust horsepower in excess of that required for straight and level flight, and the weight is expressed in pounds.

By rearranging this formula, it can be seen that :

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

Let us apply these formulas to the **PIPER NAVAJO CHIEFTAIN** :

The Chieftain weighs 7,000 lbs and has an ALL engine and SINGLE engine rate of climb of 1,390 fpm and 230 fpm respectively. By applying the formula, it can be seen that with ALL engines operating, there is 295 excess thrust horsepower available for climbing.

$$ehp = \frac{1,390 \times 7,000}{33,000} = 295$$

In the case of the **SINGLE** engine climb, there is now only 49 thrust horsepower available.

$$ehp = \frac{230 \times 7,000}{33,000} = 49$$

The actual climb performance loss with one engine inoperative can also be expressed as a percentage by using a different formula :

$$100 - \left( \frac{\text{single engine climb performance}}{\text{all engine climb performance}} \times 100 \right)$$

In the case of the Chieftain, there is an 83.45% loss of climb performance with one engine inoperative :

$$100 - \left( \frac{230}{1,390} \times 100 \right) = 83.45\%$$

Let's see how the **CESSNA 310** fares.

The Cessna 310 weighs 5,300 lbs and has an ALL engine rate of climb of 1,495 fpm, and a SINGLE engine rate of climb of 327 fpm. With all engines operating, 240 thrust horsepower is available for the normal climb :

$$ehp = \frac{1,495 \times 5,300}{33,000} = 240$$

In the case of the single engine rate of climb, it can be seen that the amount available is reduced to 52 thrust horsepower :

$$ehp = \frac{327 \times 5,300}{33,000} = 52$$

Expressing the loss in climb performance with one engine inoperative as a percentage :

$$100 - \left( \frac{327}{1,495} \times 100 \right) = 78.13\%$$

The following figures, which were provided by the American Federal Aviation Administration as part of their General Aviation Accident Prevention Program, should be enlightening :

### PERFORMANCE LOSS OF REPRESENTATIVE TWINS WITH ONE ENGINE INOPERATIVE

#### PISTON ENGINE

	All Engine Climb (fpm)	S.E. Climb (fpm)	% Loss
Beech Baron 58	1694	382	80.70
Beech Duke	1601	307	80.82
Beech Queen Air	1275	210	83.53
Cessna 310	1495	327	78.13
Cessna 340	1500	250	83.33
Cessna 402B	1610	225	86.02
Cessna 421B	1850	305	83.51
Piper Aztec	1490	240	83.89
Piper Navajo Chieftain	1390	230	83.45
Piper Pressurised Navajo	1740	240	86.21
Piper Seneca	1860	190	89.78

#### TURBOPROPS

	All Engine Climb (fpm)	S.E. Climb (fpm)	% Loss (fpm)
Beech King Air E90	1870	470	74.87
Mitsubishi MU2-J	2690	845	68.59
Rockwell Commander 690A	2849	893	68.66
Swearingen Merlin III	2530	620	75.49



**BUSINESS JETS**

	All Engine Climb (fpm)	S.E. Climb (fpm)	% Loss
Cessna Citation	3100	800	74.19
Falcon F	3300	800	75.76
Falcon 10	6000	1500	75.00
Gates Learjet 24D	6800	2100	69.12
Grumman Gulfstream II	4350	1525	64.94
Hawker Siddeley HS125-600	3550	663	81.32
IAI 1123 Westwind	4040	1100	72.77
Rockwell Sabre 75A	4300	1100	74.42

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**ENGINE-OUT ANGLE OF CLIMB  
(DEGREES, AT BEST-RATE SPEED)**

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

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

When examining the Performance Loss With One Engine Inoperative Charts which show the single engine climb performances achieved by various aeroplanes, keep in mind that the results were obtained under ideal conditions, with the aeroplane in the CLEAN configuration, i.e. with the gear and flap retracted and the propeller feathered.

Out of interest, let us now compare these single engine climb figures with the single engine climb performance the aeroplane had to achieve for certification which, as we know, was determined using the formula  $ROC = 0.027 V_{so} \text{ squared}$ .

We already know that for certification, FAR 23 requires the manufacturers of light twin engine aeroplanes which :

- (a) weigh **MORE** than 6,000 lbs, and **ANY** aeroplane with a stalling speed **HIGHER** than 61 kts, to **DEMONSTRATE** a steady rate of climb of at least  $0.027 V_{so} \text{ squared}$ , and those which
- (b) weigh **LESS** than 6000 lbs, and have a stalling speed **LESS** than 61 kts, to **DETERMINE WHETHER** or **NOT** the aeroplane can achieve a steady rate of climb of  $0.027 V_{so} \text{ squared}$  i.e. there is no requirement for a positive rate of climb.

In all cases FAR 23 requires that the tests will be completed at 5000 ft - in still air conditions - at ISA temperature - the gear and flap in most favourable (best lift/drag) position - the critical engine stopped and the propeller of that engine feathered.

The Piper Navajo Chieftain weighs in excess of 6,000 lbs, and was therefore required to **DEMONSTRATE** a rate of climb of at least  $.027 V_{so} \text{ squared}$ .  $V_{so}$  for the Chieftain is 74 kts, thus for certification the minimum single engine climb performance the Chieftain was required to demonstrate at 5,000 ft was  $.027 \times 74 \times 74$ , or 147.8 fpm. As the Chart figures show, with the gear and flap retracted, the single engine rate of climb obtained by the test pilot was 230 fpm - in fairness however, the 230 fpm figure was determined whilst the aeroplane was operating at maximum weight of 7,000 lbs. Naturally, at weights less than maximum weight, the rate of climb would be much better, but this could also be nullified by such things as a temperature in excess of ISA, the condition of an aeroplane, piloting ability and the presence of turbulence.

The Cessna 310 which weighs less than 6,000 lbs but stalls at 63.9 kts was also required by FAR 23 to **DEMONSTRATE** a single engine climb of at least 110.2 fpm - it actually achieved 119 fpm in the  $V_{so}$  configuration. The Chart figures show, with the gear and flap retracted, the single engine climb rate obtained was 327 fpm.

On the other hand, because the Piper Aztec stalls at 60.78 kts i.e. less than 61 kts and weighs less than 6,000 lbs, the manufacturer was only required by FAR 23 to **DETERMINE** whether the aeroplane had a positive or negative rate of climb when the formula  $ROC = 0.027 V_{so} \text{ squared}$  was applied. There was no requirement to **DEMONSTRATE** a rate of climb - however it did have a 50 fpm climb and this increased to 240 fpm with gear and flap retracted.



It can be seen from the Single Engine Rate of Climb Chart figures that the climb performance capability with the gear and flap retracted for light twin aeroplanes is still not very good, especially when one considers that the results were achieved in a "factory fresh" aeroplane flown by a professional pilot in ideal conditions.

It is also interesting to note that some light twins which were required by FAR 23 to **DEMONSTRATE** the ability to meet the  $0.027 V_{SO}^2$  single engine rate of climb, still had to be weight limited.

The FAA, as part of an Accident Prevention Program, also provided an example of single engine climb performance following an engine failure on take-off, quoting a well known light twin, and after taking into consideration various factors such as the pilot not using the complete runway available, pilot reaction time, time to actually complete the feathering, a temperature above ISA, and the existence of turbulence at the time of take-off, the conclusion was that the aeroplane would have travelled in excess of 9 nautical miles before achieving 500 ft - and pilot inexperience and poor visibility were not taken into consideration!

There are many factors which can affect the single engine climb performance of these light twin engine aeroplanes :

1. AEROPLANE CONDITION : in an older aeroplane, the single engine climb rate could be as much as 150 fpm less than that achieved for certification. Anything which reduces engine power, such as low compression or weak ignition, or which interferes with the streamlined airflow over the wings, fuselage and tail surfaces, can erode performance - even small dints, misfitting doors or hatches, certainly ice formation on the wings, will destroy the normal airflow, not to mention the weight penalty.
2. AEROPLANE PERFORMANCE : if the undercarriage or flap have not been retracted, the propeller is not feathered, and the temperature is above ISA - then the performance of the aeroplane will be drastically reduced.
3. AIRSPEED : an increase or decrease of 10 kts from  $V_{YSE}$  (best rate of climb single engine) can result in a climb reduction of some 30-40 fpm.
4. LANDING GEAR : if the landing gear is extended, the rate of climb can be reduced by 200 fpm. Furthermore, on some aeroplanes, retraction of the undercarriage results in an additional increase in drag, particularly an aeroplane which has doors which are closed with the gear down but open during retraction. This could cause a critical situation at low airspeeds and at a low altitude. The drag from an extended undercarriage can cause the airspeed to reduce at the rate of 3 kts per second.
5. FLAP POSITION : if the wing flaps are not retracted to the optimum position for climb as defined in the Flight Manual, as much as 75-100 fpm climb rate can be lost for each additional 10 degrees of flap deflection.



6. COWL FLAPS : if the cowl flaps are not closed on the failed engine, a 25-50 fpm climb reduction can be anticipated.
7. AERODYNAMIC SLIP : unless the test pilot's techniques and standard of flying can be achieved, there is every likelihood that, whilst endeavouring to eliminate the aerodynamic slip, the climb performance will be further seriously eroded instead of being improved.

On the other hand, should a pilot elect **NOT** to eliminate the aerodynamic slip, and to fly wings level with the "balance" ball centred, this will only marginally **DECREASE** the aeroplane's single engine climb performance (can be as little as 20 fpm), however a **HIGHER V<sub>mc(a)</sub>** must be anticipated.

Eliminating the aerodynamic slip should only be **CONSIDERED**, following an engine failure, **AFTER** the propeller has been feathered and the aeroplane "precision" trimmed.

It is suggested you should, at this stage, refer to the more detailed information about aerodynamic slip starting at page 30 of the definitions.

8. TEMPERATURE : an increase in temperature of 10 degrees can reduce the rate of climb by about 20-30 fpm.
9. PROPELLER DRAG : energy is extracted from the air stream by a windmilling propeller and, like all aerodynamic drag, it increases as the square of the velocity increases, and can result in a loss of climb rate of up to 400 fpm, depending on the propeller design (the light twin engine aeroplane has a climb rate loss of 100-200 fpm) - some windmilling propellers can cost 3 kts per second in airspeed.
10. ALTITUDE : a significant reduction in climb capability must be expected at high altitude (in other than turbine powered aeroplanes), or at density altitudes in excess of 5000 ft. Generally speaking, for the light twin aeroplane fitted with normally aspirated engines, the rate of climb will decrease approximately 30 fpm for each 1000 ft increase in altitude. If the aeroplane has turbo charged engines, the rate of climb can be expected to decrease by up to 10 fpm for each 1000 ft increase in altitude.
11. AEROPLANE WEIGHT and BALANCE : as take-off weight is increased, the subsequent rate of climb decreases markedly in the single engine configuration. The Cessna 402A graph shows that at 4300 lbs (1950 kg), the sea level single engine rate of climb is 900 fpm - and at 6300 lbs (2858 kg), it decreases to 240 fpm.

The rate of climb on one engine can vary by approximately 15/20 fpm for each 1% change in weight. Naturally, the less weight being carried, the better the situation e.g. if taking off from an aerodrome at 3000 ft above mean sea level, a reduction of 5% in the take-off weight will offset the reduced rate of climb due to altitude.

12. POSITION of C of G : the position of the C of G affects the yawing force present after engine failure - remembering that an aeroplane yaws about its C of G. With an aeroplane with a forward C of G, the turning moment of the operative engine is minimum, whilst the correcting moment of the rudder is maximum. With an aft C of G, the turning moment of the operative engine is much greater whilst the correcting moment of the rudder is minimum, so a much higher  $V_{mc(a)}$  exists.

Besides decreasing pitch stability, an aft C of G will make the loss of an engine more critical and, in a tight situation, this could be disastrous.

13. ENVIRONMENT : If an engine quits after dark or when visibility is restricted by weather, chances are that pilot performance will be affected - especially with only a one man crew. A pilot has to maintain control of the aeroplane while going through all the steps in his emergency procedure, and this may take longer than in visual daytime conditions. In a real life situation, the pilot may not make any big mistakes, but the margin of error could be too slim for even small mistakes.
14. TURBULENCE : is another little recognised environmental factor. Turbulence degrades potential climb rate with one engine out and increases the control problem. The possible presence of wind shear should be regarded as particularly hazardous.
15. AIR-CONDITIONING : loss of performance could occur if an air-conditioner is "on" and its compressor is mounted on the operating engine, as it uses engine power which could be converted to thrust for climb performance.
16. ELECTRICAL LOADS : by reducing electrical loads, thrust can be marginally increased on the good engine, as it takes power to produce electricity.
17. PILOT REACTION TIME : medical experts claim that it takes seven seconds for a pilot to react to an engine failure situation.
18. PILOT EXPERIENCE : certainly, the more experienced pilot should be better equipped to handle the engine failure situation.

To sum it up, it can be said that :

- \* Failure of an engine in a light twin engine aeroplane, certified in accordance with the FAR 23 requirements, will decrease sea-level performance by between 78-90%.
- \* The test pilot's results may not be achievable in your aeroplane as there is no allowance made for the real life factors listed above. (If the aeroplane was operating at less than its maximum take-off weight, this naturally would be a bonus).



- \* There is nothing in the Australian or American regulations governing the certification of light twin engine aeroplanes which says they must be able to fly (maintain height or climb) whilst in the **TAKE-OFF** configuration, with one engine inoperative.
  - \* With regard to performance (but not controllability) in the take-off or landing configuration, the light twin engine aeroplane is considered, for certification, to be merely a single engine aeroplane with the power divided into two packages.
  - \* Because the take-off and initial climb are considered to be all engines operating manoeuvres, the Flight Manual take-off distance and take-off climb data are scheduled on this basis.
  - \* Where there is an approved **FOREIGN** Flight Manual or a Manufacturer's Data Manual that sets out take-off and landing distances required for that aeroplane, these figures could be **UNFACTORED**.
  - \* Unless a pilot can be assured that the aeroplane to be flown is capable, in the event of an engine failure in IMC, of at least maintaining LSA, thought should be given to planning by a more practical route.
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- \* To give yourself maximum protection, (unless you know your aeroplane is capable, in the event of an engine failure following take-off, of climbing to LSA), the cloud base at the time of departure needs to be above the circling minima to allow a visual circuit should a return for landing be necessary. If you elect to take off with a lower cloud base, treat your aeroplane as a single engine aeroplane - and after all, single engine aeroplanes do fly quite safely in IMC.
  - \* A thorough appreciation and understanding of the performance capability of the light twin aeroplane is necessary because, without this knowledge, safety standards can unknowingly be jeopardized, irrespective of the experience level of the pilot in command.

Whilst the subject of engine failure has been discussed at length, it must again be stressed that the chances of an engine failure in a single or twin engine aeroplane are highly unlikely, provided pilots always :

- a/ complete thorough pre-flight inspections with particular attention being paid to the fuel quantity and fuel contamination
- b/ use the weight and balance charts in the Flight Manual
- c/ make correct use of Check Lists
- d/ ensure the aeroplane has been properly maintained



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**ENGINE FAILURE IN THE LIGHT TWIN**

**and**

**ASYMMETRIC FLIGHT**

## ENGINE FAILURE IN THE LIGHT TWIN

and

### ASYMMETRIC FLIGHT

It is not the intention in this section to discuss the actual endorsement, but rather to offer some practical suggestions and advice, particularly in the area of ASYMMETRIC i.e. flight following an engine failure.

As emphasised throughout this book, the possibility of an engine failure in single or multi-engine aeroplanes is remote, however failures can occur, and this is why the sequence must be covered during endorsement training.

Engine failure is introduced by many instructors at the very start of the multi engine endorsement - this is wrong. The **CORRECT TIME** to introduce the sequence is when the pilot completing the endorsement has mastered flying the aeroplane in its normal configuration - after all, this is how the sequence is handled in the single engine aeroplane!

In any light twin engine aeroplane, lift-off and during the initial climb are the most critical periods should an engine failure occur.

Pilots must accept that there are many situations and circumstances when most light twins are incapable of climbing out, or continuing flight should an engine fail shortly after take-off.

More often than not, if the failure occurs before reaching a safe manoeuvring height, there may be little option other than to close the throttles and adopt the same technique recommended in the case of an engine failure in a single engine aeroplane. Any other course of action could entail unacceptable risks in the form of possible loss of control.

Whilst a pilot's instinct may be to try and remain airborne, before contemplating such an action, it is necessary to know for certain that the aeroplane is **CAPABLE** of maintaining or gaining altitude in an engine out situation. Pilots must also be aware of the procedure to be followed if the aeroplane is **NOT CAPABLE** of continued flight.

It must also be remembered that even when the aeroplane has a climb capability, this climb capability still may not be sufficient to clear the terrain or obstacles located on the take-off path.

Throughout this book it has been stressed that there is no regulatory requirement for continued take-off capability for light twin aeroplanes in the event of an engine failure. In fact there is much truth in that somewhat cynical statement that "many light twin engine aeroplanes are merely single engine aeroplanes with their power divided into two individual packages".



Whilst the capability of **EN ROUTE** (and don't forget en route does not mean immediately following take-off) continuation of flight after an engine failure is usually there, it will still be dependent on whether ;

- (a) there are any terrain clearance problems
- (b) the aeroplane is at a "safe" height at the time of the engine failure
- (c) the undercarriage and the flaps are retracted
- (d) the propeller is feathered
- (e) the pilot is proficient
- (f) the aeroplane is being flown in a professional manner

It is still a fact however, that it is often just not possible for most light twins to climb away in the event of an engine failure **SHORTLY AFTER TAKE-OFF**, even if the **OPTIMUM** configuration is quickly achieved and faultless pilot performance is exhibited.

For this reason the safest and most practical attitude for all pilots to adopt is to approach any light twin aeroplane on the basis that it is a **SINGLE ENGINE AEROPLANE** until it reaches a height of approximately 400 ft.

This doesn't mean that the 400 ft height cannot be "concessioned" - it can, but only after many factors have been taken into consideration. It is possible, having considered these factors, that the ultimate decision may even be to treat the aeroplane as a single engine aeroplane to a height well in excess of 400 ft. Whatever "**DECISION HEIGHT**" is finally selected, be certain that the selection of this height is based on **FACTS** and not on **FANTASY**.

When we talk of a **DECISION HEIGHT**, we are defining the height in a light twin engine aeroplane where, in the event of an engine failure following take-off, the climb out will continue, the engine will be shut down and its propeller feathered. **BELOW** this **DECISION HEIGHT**, the throttle on the operating engine will be closed and a landing attempted.

The reasons 400 ft is recommended as a practical "**INITIAL DECISION HEIGHT**", (remember, it can be concessioned provided there is sufficient justification), are :

1. At 400 ft, the gear and flap would have been retracted, the airspeed should be stabilised, and there is height which can be traded, if necessary, for airspeed.
2. Whilst a high degree of skill and precision is desirable, it is not essential, as height, speed and a "clean" aeroplane equate to time - which means that even pilots with average ability should be able to handle the situation.

3. The time it takes to achieve the actual feathering of the propeller.

Without including a pilot's "reaction" time, completing the engine shut down and feathering items of the Engine Failure Check List i.e.

- a. FLY THE AEROPLANE (regain DIRECTIONAL CONTROL)
- b. POWER
- c. GEAR and FLAPS
- d. POSITIVE IDENTIFICATION
- e. PROving and FEATHERING

will take even the most competent pilot at least 20-25 seconds. Confirm these times using a stop-watch (no need to be in an aeroplane), and you may be surprised at the time it takes.

Even with an "obvious" engine failure which would necessitate the **IMMEDIATE** feathering of the propeller i.e.

- a. FLY THE AEROPLANE (regain DIRECTIONAL CONTROL)
- b. FEATHER (move pitch control to the feather position)

there is still an element of time involved, particularly when pilot reaction time is taken into consideration.

4. In the section titled PERFORMANCE, we saw that the factory fresh aeroplane, flown by a highly skilled test pilot in ISA temperature and in ideal weather conditions, could only achieve a climb rate, with the gear and flap retracted and the propeller feathered, of 200-300 fpm.

Before "concessioning" the 400 ft height and nominating a different **DECISION HEIGHT**, the following factors must be taken into consideration :

1. Aeroplane condition (engines, airframes and propellers)
2. Take-off weight
3. Airport elevation, runway length and surface
4. Density altitude (pressure altitude and temperature)
5. Humidity
6. Wind direction and speed
7. Turbulence
8. Environmental conditions i.e. day or night
9. Piloting experience, ability, and recency
10. Height of terrain on departure track (this could also determine the preferred runway)
11. Pilot reaction time (remember, experts quoted 7 seconds as a minimum)
12. The time it takes until the propeller is feathered
13. Aerodynamic slip - ability to eliminate

Let us now look at what penalties, in the form of loss of climb performance, can be expected from some of the factors listed on the previous page.

	<u>FEET PER MINUTE</u>
LANDING GEAR EXTENDED	200
FLAPS	75-100 each 10 deg. above optimum
WINDMILLING PROPELLER	100 - 200
COWL FLAPS	25 - 50
VARIATIONS TO $V_{y_{se}}$	30 - 40
PRESSURE HEIGHT	30 per 1000 ft
TEMPERATURE	20 - 30 per 10 degree C.
A/C WEIGHT	20 per 1% incr. in weight
AERODYNAMIC SLIP (NOT ELIMINATED)	Marginal - could be as little as 20
CONDITION OF AEROPLANE	UP TO 150
PILOT'S ABILITY	?
TURBULENCE/ENVIRONMENT	?

Where a pilot, after taking everything into consideration, settles on a **DECISION HEIGHT BELOW 400 ft.** it should still be remembered that the further you come down the take-off flight path and **CONCESSION** the 400 ft, there is less height, possibly less airspeed, and certainly less time available - which all means greater precision is necessary to be able to control and fly the aeroplane, shut down the engine and feather the propeller.

Remember that with one engine inoperative, the light twin aeroplane does not have the capability to accelerate, and only height can be traded for speed - and in the early stages following take-off, there just isn't any height to trade.

Unfortunately, during training, pilots often get the wrong impression about the single engine climb capability of their twin aeroplane when an instructor fails an engine following take-off - the reason for this is that the instructor unintentionally provides something well in excess of zero thrust, when he simulates the effect of a feathered propeller.

It might be argued, why not use a **DECISION AIRSPEED** as the parameter which will determine whether flight will be continued in the event of an engine failure following take-off. **DECISION AIRSPEEDS ARE IMPORTANT - THEY MUST BE KNOWN**, but, even if these speeds have been reached, there can be many occasions when continued flight **MAY STILL NOT BE PRACTICAL**, simply because other factors and considerations would make such a decision irresponsible.

What we are saying is that there is a **DECISION AIRSPEED AND A DECISION ALTITUDE**, and **BOTH** must be achieved before flight can be continued in the event of an engine failure following take-off. Whilst the **DECISION AIRSPEED** normally remains constant, the **DECISION ALTITUDE** could well vary with every take-off.



Let's now see what a pilot can do to improve his survival chances in the event of an engine failure - these will be discussed under the following headings :

1. Before flight
2. Pre-flight inspections
3. Procedure at holding point prior to actual take-off
4. The actual take-off
5. The initial climb
6. Asymmetric turns
7. Asymmetric circuits and landings
8. The asymmetric go-around
9. How engine failure should be simulated
10. Actual feathering of propellers
11. The engine failure check list
12. How the asymmetric training sequences should be handled

## 1. BEFORE FLIGHT

Before even entering the aeroplane, a pilot should, having taken everything into consideration, know the best runway to use, the airspeeds which will be flown, and what he intends to do in the event of an engine failure during or following take-off. He should review the **DECISION AIRSPEEDS** and decide on his **DECISION HEIGHT** which in either case, if an engine fails **BEFORE** being reached, the throttle on the operating engine will be closed and a landing attempted. The point to be emphasised is that these "decisions" should be made **WELL BEFORE ENTERING THE AEROPLANE**.

## 2. PRE-FLIGHT INSPECTIONS

Pre-flight inspections must be thorough - do your checks for a **REASON**. Correct use of Check Lists goes hand in hand with good airmanship - airmanship simply means - **DON'T THINK, BE SURE!** Airmanship is what a pre-flight inspection is all about. Don't trust anyone else - confirm the fuel quantity yourself by a visual inspection, ensure the fuel caps are correctly closed, the oil quantity is acceptable and the cap is secured - and what is of paramount importance, ensure that there is no fuel contamination.

All the other "normal" checks should also be thorough. Pilots careless in their approach to checks will often also display an irresponsible approach and attitude to the rest of their flying.

## 3. PROCEDURE AT (OR WHILST TAXYING TO) THE HOLDING POINT PRIOR TO ACTUAL TAKE-OFF

Assuming proper cockpit and engine checks have been completed, again "condition" yourself and re-affirm any departure requirements or instructions, and your intentions should an engine fail during or after take-off. After this "conditioning" there should be no other distractions and no general talk with passengers until the aeroplane is well established in the climb, with all after take-off checks completed and other requirements associated with flying the aeroplane being satisfied.

#### 4. THE ACTUAL TAKE-OFF

On line-up, avail yourself of the full runway length whenever possible - runway behind is of no value.

As already stated, in any aeroplane, take-off and the initial climb are the most critical periods should an engine malfunction occur.

There are obviously a number of take-off and climb out techniques available. How then is a pilot going to decide which one to use which will provide the greatest protection in the event of an engine failure?

The extremes in take-off technique are to :

- a/ hold the aeroplane down and pass the far end of the runway at 30 - 50 ft, at cruising speed or higher, or
- b/ pull the aeroplane into the air below  $V_{mc(a)}$  and climb away at a low airspeed

If one considers the possibility of an engine failure somewhere during the initial climb out, neither of these techniques make much sense for the following reasons.

Drag increases as the square of the speed, so for any increase in speed over and above the best single engine climb speed, the greater the drag, and the less climb performance an aeroplane will have. At 105 knots, the drag is approximately 1.5 times greater than at 87 knots. At 124 knots, the drag has doubled, and at 174 knots it is approximately 4 times as great as at 87 knots.

Whilst the drag is increasing as the square of the speed, the power required to maintain a speed increases as the cube of that speed. The argument that a pilot can convert excess speed to altitude is not valid, as power is being wasted to accelerate the aeroplane.

Naturally, if the take-off was being made on a 13,000 ft runway, there could be some compromise - in other words, the pilot in command could exercise his command prerogative.

On the other hand, trying to gain height too fast can also be dangerous because of the control problems in the event of an engine failure.

One further point to make is that the aeroplane should never leave the ground below a speed of  $V_{mc(a)}$  plus 5 knots.

It is again emphasised that every pilot should know, prior to entering the aeroplane, the best runway to use and what he will do in the event of an engine failure.

#### 5. THE INITIAL CLIMB

It is often stated that the climb airspeed following take-off in a light twin engine aeroplane, with all engines operating, should not be less than  $V_y$  (best single engine rate of climb speed shown by a **BLUE LINE** on the airspeed indicator) - remembering this speed decreases with altitude, and not faster than  $V_y$  (best rate of climb speed all engines operating). Unfortunately, interpreting this rather broad statement is difficult.



The problem with the statement is that even if the best rate of climb all engines operating speed ( $V_y$ ) is used, there still may not be a sufficient buffer above the best single engine rate of climb speed ( $V_{yse}$ ) in the event of an engine failure.

Whilst the **ACTUAL** airspeed which can be used will **STILL** be dependent on the climb performance of the particular aeroplane type, it is recommended that, **PROVIDED** a suitable climb gradient can be achieved, wherever possible a speed of  $V_{yse}$  plus 10 to 15 knots be used, **UNLESS** the best rate of climb all engines operating speed ( $V_y$ ) is higher, in which case this  $V_y$  speed should be flown.

The reason for recommending  $V_{yse}$  plus 10 to 15 knots is that this caters for piloting experience and ability. Whilst the very experienced pilot, having taken everything into consideration, may elect to use  $V_{yse}$  plus 10 knots, this does not mean that there would be anything wrong with the less experienced pilot using  $V_{yse}$  plus 15 knots. A **COMPETENT** pilot is one who makes **RESPONSIBLE COMMAND DECISIONS**.

The reason for flying a "buffer" speed above  $V_{yse}$  until a safe manoeuvring height (approx. 500 ft) is obtained, is that at least 10 to 15 knots airspeed can be expected to be lost in the event of an engine failure, (with the gear retracted), whilst the propeller is being feathered - unless of course height can be traded for airspeed, which is not always possible. Naturally the aeroplane would need to be **ABOVE** your **DECISION HEIGHT** before feathering and continued flight could be contemplated.

Whilst the chances of an engine failure may be remote, these "buffer" speeds should always be flown (provided of course that a sufficient climb gradient can be achieved) until reaching a safe manoeuvring height, at which time the normal climb profile speed should be flown.

By using  $V_{yse}$  plus 10 to 15 knots, (or  $V_y$  if this is a higher speed), and **PROVIDED** the undercarriage has been retracted, any pilot who is reasonably competent in engine failure and feathering procedures, should have an airspeed close to the best single engine rate of climb speed ( $V_{yse}$ ) by the time the propeller feathers. Pilots should however appreciate that it may still be necessary to make a slight pitch attitude change to achieve  $V_{yse}$ .

**$V_{yse}$  PLUS 10 KNOTS** should be your **MINIMUM DECISION AIRSPEED**.

Whilst there is a lot of talk about trading height for airspeed, it must be remembered that there are many occasions when there is no height to trade and, even if there is, trading height for airspeed requires a high degree of skill and precision flying, not always achievable in an actual emergency situation. Many pilots will also experience a psychological reluctance to lowering the aeroplane's attitude (or nose position of the aeroplane) at low altitudes to achieve this extra airspeed.

It is a fact that an acceptable climb gradient may not always be available in cases where the  $V_{yse}$  plus 10 to 15 knots is **HIGHER** than the manufacturer's best rate of climb all engines operating airspeed ( $V_y$ ). Where such a situation exists, your instructor will advise you of the best compromise airspeeds to use.



There could also be occasions when there is a need to climb away at  $V_x$  (best angle of climb speed all engines operating). Should this be necessary, your **DECISION HEIGHT**, above which continued flight is proposed in the event of an engine failure, certainly would need to be carefully assessed.

Whilst it might seem that undue emphasis has been placed on airspeeds which should be flown, this was **NEVER** the intention. A pilot flies a **PITCH ATTITUDE** to achieve an airspeed, and all pilots must learn to recognise these attitudes, whether using the Flight Attitude Indicator or the Flight Director during **INSTRUMENT FLIGHT**, or the "NOSE" of the aeroplane during **VISUAL FLIGHT**. ("Nose" refers to the area forward of the windscreen). If the **ATTITUDE** is right and the airspeed is **BELOW THE REQUIRED AIRSPEED**, you have a problem which will call for an immediate command decision.

You will note that so far, no mention has been made of what airspeed is required prior to the gear/flap being retracted. The reason for this is that the aeroplane will normally be accelerating during this phase of flight and, if the gear is still extended and an engine failure occurs, normally there is no option other than to close the throttle on the operating engine and endeavour to carry out a "controlled" landing, hopefully on the remaining runway available. This is one of the main reasons why **ALL** available runway should be used for take-off.

Certainly, there may be situations where a light twin engine aeroplane can be flown away following take-off in the event of an engine failure, prior to the gear being retracted, but this will require a high degree of skill and precision flying, and is not recommended for the average pilot.

With a windmilling propeller and the gear down, but still with the original climb angle, the pilot who does everything exactly by the book can still expect the airspeed to decrease by a **MINIMUM** of 15 knots by the time the gear can be retracted and the propeller feathered.

Looking at it in another way - with the gear extended, the rate of climb can be reduced by up to 200 fpm, and a windmilling propeller can further reduce the climb rate by 100 - 200 fpm. Couple this with "pilot reaction time" and it can be seen why continued flight, in the event of an engine failure before the gear has been retracted, is not recommended.

In the event of an engine failure following take-off, even with the propeller feathered and gear and flap retracted, if the airspeed is below  $V_{yse}$  and there is no height to trade, the safest course is to descend straight ahead under control and accept the consequences.

Pilots who have **NOT** "conditioned" themselves to what action they will take in the event of an engine failure following take-off will most likely continue with shocked disbelief, trying to hold altitude until the aeroplane finally stalls and spins, or builds up an uncontrollable sink rate and crashes into the ground.

The message here is : **DON'T TRY TO DO SOMETHING BEYOND YOUR OWN CAPABILITIES OR THE CAPABILITIES OF YOUR AEROPLANE - DO SO, AND YOU ARE COURTING DISASTER!**

Many pilots are also in the habit of reducing power shortly after take-off. This technique is **INCORRECT** and **DANGEROUS**. Leave your throttles alone (provided maximum take-off power is not being exceeded) until your aeroplane reaches at least 4/500 ft, or what you know to be a safe manoeuvring height. Besides being the correct technique, it is also "cheap insurance".

In summary it can be said :

1. Prior to entering the aeroplane, know the **BEST RUNWAY** to use, the **AIRSPEEDS** to be flown, and your "go-no-go" **DECISION HEIGHT** and **DECISION AIRSPEEDS**
2. Wherever possible, use **ALL** the available runway
3. Prior to take-off, **AGAIN** "condition" yourself for what action you intend to take in the event of an engine failure during the take-off or the climb out, and after you have "conditioned" yourself, **DON'T BE DISTRACTED**
4. **NEVER** rotate the aeroplane below minimum control speed plus 5 knots, or the manufacturer's recommended speed
5. In the event of an engine failure prior to your undercarriage (flap) being retracted, remember that the **SAFEST PROCEDURE** is to close the throttle of the operating engine and to endeavour to carry out a "controlled" landing
6. Once the aeroplane is cleaned up, i.e. gear and flap have been retracted, **CLIMB** at Vyse plus 10 to 15 knots (assuming this airspeed provides an acceptable climb gradient) or Vy, should this latter speed be higher
7. Do **NOT** reduce take-off power until reaching a safe manoeuvring altitude (a minimum of 400 to 500 ft in normal circumstances)
8. On reaching a **SAFE** manoeuvring height, providing there are no engine problems, the normal attitude/airspeed profile should now be flown

Proficiency in flying can only be obtained and maintained by practising the procedures with a competent flight instructor. In simulated engine failure exercises, a pilot should be able to assess and recognise his own limitations and, as a result, be capable of making practical and sensible decisions when operating as the pilot in command.

## 6. ASYMMETRIC TURNS

When turning the aeroplane, try, whenever possible, to make the turn towards the **OPERATING** engine - particularly when the airspeed is low. As we already know, Vmc(a) can be higher if wing down towards the operating engine is not achieved. It is a fact that aeroplanes certified after the mid 1960's were required to demonstrate the ability to turn towards the failed engine, however this exercise was always carried out at speeds well in excess of Vmc(a). The rule is to always try to turn towards the **OPERATING** engine, especially when the aeroplane is being operated in any low speed configuration.



## 7. ASYMMETRIC CIRCUITS AND LANDINGS

Try whenever possible in an asymmetric situation to fly the normal circuit pattern.

It is most important to know and remember that **THROTTLE CONTROLS YOUR AIRSPEED** - such things as gear and flap can only **AFFECT** the airspeed.

For the average light twin engine aeroplane, you should aim for 100/105 kts just as you start your turn to base. On base, your speed should be 95/100 kts i.e. about 15 kts above Vyse - and on final, 90/95 kts, with subsequent reductions in speed on final to achieve the threshold speed. Provided there is ample runway, do not be frightened to increase your normal threshold speed by 10 kts. (10 knots in a light twin equates to approximately 300 ft of runway).

The undercarriage should be lowered when you have been able to reduce the manifold pressure (boost) to 23 inches. This prevents drag from unnecessarily opposing power. Your next power to be achieved will be between 17/19 inches, depending on the aeroplane type, and this should be achieved on base leg. At this stage, you can take the first and possibly second flap setting.

The final power reduction should be between 14-17 inches, again depending on the aeroplane type. On reaching this final power setting, when ready, final flap can be taken and the drag from this final flap should achieve the threshold approach speed. Power can then be reduced as required.

With each power reduction, the aeroplane should be retrimmed for "hands-off flying". Certainly, when the final power reduction is reached, it is a good policy to glance down to ensure the rudder trim is in the neutral position.

The power settings and the lowering of the gear and flap should be used to achieve the speeds recommended above - there is no hard and fast rule. The situation will dictate your action but, if you fly the aeroplane correctly, there should never be a need to increase power - if a power increase is necessary, it means there has been something wrong with your technique.

**REMEMBER - POWER IS THE MAIN CONTROLLER OF AIRSPEED AND THE AEROPLANE MUST BE RETRIMMED CONSTANTLY FOR "HANDS OFF".**

With practice, asymmetric circuits and approaches are not difficult - after all, if a manufacturer produced a single engine aeroplane with a wing mounted engine, everyone would want to fly it, but when building such an aeroplane, the first thing the manufacturer would do is compensate for the yawing problem, and this emphasises the importance of trimming in an asymmetric situation.

Finally, if you find yourself high on the final approach, get back onto the correct approach path simply by lowering the nose (assuming you have been flying the powers/speeds recommended above) - the speed might increase but it will quickly wash off when you resume normal profile. As with any approach, your aeroplane should be established on the correct approach path not later than the 400 ft position - that is, provided you want to take the difficulty out of the landing.



## 8. THE ASYMMETRIC GO-AROUND

Too many pilots consider that 300 ft is their **DECISION** height for a landing or a go-around.

Whilst this may be acceptable in Air Transport Category aeroplanes, it should never be considered in the light twin. **YOUR DECISION TO LAND OR NOT SHOULD BE MADE AT CIRCUIT HEIGHT.**

Certainly, a go-around can be made from a lower altitude, but it is fraught with danger. Just go back to the single engine climb performance figures shown in the **PERFORMANCE SECTION** of this book.

It may be argued that, on the plus side, you still haven't lowered the final flap and the aeroplane is not at maximum weight but, on the minus side, just consider the following :

1. The difference in your aeroplane to that used by the test pilot
2. The temperature is most likely above ISA
3. There could be turbulence
4. Your own ability in controlling the aeroplane when power is reintroduced on the operating engine
5. The possibility that, whilst endeavouring to initiate the go-around, your airspeed could get lower than  $V_{yse}$ , and yet the flap and undercarriage are still extended
6.  $V_{mc(a)}$  may be higher than the "published"  $V_{mc(a)}$

If thought is given to the problems associated with a go-around at 300 ft, any pilot will surely recognise the potential accident risk.

## 9. HOW ENGINE FAILURE SHOULD BE SIMULATED

Provided the aeroplane is at height, the correct method of simulating engine failure is by use of the mixture control whereas, with any exercise involving engine failure after take-off, the throttle should be used and, even so, it should be closed slowly.

After all, what must be borne in mind at all times is that, in simulating engine failure, an actual emergency has been created, and this is why asymmetric training in the take-off and initial climb should be treated with the utmost respect.

Far too many accidents occur during training exercises. With low houred pilots, there is just not sufficient time in any endorsement training to make the pilot under training an expert in asymmetric flying. All that can be hoped for is that he has a sound appreciation of the exercise, acquires some degree of skill, and is fully aware of his own limitations and the limitations of his aeroplane.

More emphasis should be placed on the prevention of engine failures, by ensuring correct "checks" are completed, and only well maintained aeroplanes are flown.

## 10. ACTUAL FEATHERING OF PROPELLERS

Whilst the pilot under training must obviously experience the "psychological" effects of seeing a propeller feathered, aeroplanes used for this exercise should be equipped with unfeathering accumulators.

Probably, all that is required during the endorsement is for one landing with the engine shut down and the propeller feathered.

Zero thrust should always be used during asymmetric training. If the setting is not provided by the manufacturer, 10 to 12 inches of boost and approx 2200 RPM will normally be somewhere near the figure.

There can be a further problem with feathering propellers, and an Aeronautical Information Circular was issued by the U.K. Civil Aviation Authority drawing attention to the possibility of propeller feathering difficulties in light twin engine aeroplanes. The information is applicable to pilots and operators of such aeroplanes anywhere. The article states :

"Most feathering propellers fitted to light, twin piston-engine aeroplanes (hydraulically actuated, constant speed, such as some Hartzell and McCauley types), are designed in such a way that it is not possible to feather the blades below a certain RPM (typically 700-1000 rpm).

At these low RPM, centrifugal latches operate to hold the blades in fine pitch, which ensures that when the engine is shut down on the ground, the subsequent restart is not made with the propellers feathered.

In cases where the normal windmilling RPM at low airspeed may fall low enough to prevent feathering, the Flight Manual, Owner's Handbook or Pilot's Operating Handbook warns the pilot that feathering cannot be accomplished below a certain RPM. However, the full implications of the situation may not always be clear and pilots should be aware of these other factors :

- \* In the event of an engine failure caused by a major mechanical fault, e.g. seizing bearings due to loss of oil, engine deceleration rate can be rapid and it is thus imperative that immediate action is taken to feather the propeller before the RPM reaches the 1000 mark.
- \* On most twins, the usual procedure when shutting down an engine that has failed is initially to close the throttle of the inoperative engine. This is to confirm which engine has failed before commencing feathering action. However, if the windmilling RPM has reduced towards the critical region where feathering may not be successful, re-opening the throttle will usually increase the RPM slightly and improve the probability of being able to feather.

- \* In the event of an engine failure, it is important not to let the airspeed decay below the scheduled engine-out climb speed. This helps to ensure that the propeller continues to windmill at sufficiently high RPM for successful feathering. If optimum performance is required, it is vital to achieve and maintain the best engine-out climb speed.
  - \* The loss of performance associated with a stopped propeller in fine pitch or, more importantly, with a windmilling propeller, is potentially serious. The additional drag will considerably reduce the single-engine climb performance below that available with a fully feathered propeller. Directional controllability will be reduced also, though adequate control should still be available down to the minimum control speed  $V_{mc(a)}$ .
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# 11. THE ENGINE FAILURE CHECK LIST

## ENGINE FAILURE - PRECIS OF ACTIONS

1. **FLY AEROPLANE** - remember, to maintain a command heading, RUDDER is the primary controller of yaw
2. **POWER** - must always be considered - do NOT get on backside of power curve
3. **PERFORMANCE** - Gear - Flaps

\*\*\*\*\* **DECISION** ... Feather or Rectify

## 4. **FEATHERING**

a/	Throttle	- prove		a/	Throttle	- prove
b/	Mixture		<u>OR</u>	b/	Feather	
c/	Feather			c/	Mixture	

REPEAT ALOUD AS YOU CARRY OUT THE ABOVE ACTIONS

- i.e. - LEFT Engine Failed - LEFT Throttle  
 - LEFT Mixture - LEFT Feather (or whatever order the manufacturer recommends).

**APPROXIMATE TRIM** <<<<<<>>>>>> **most important**  
 - Cowl flap(s) - but only if necessary

\*\*\*\*\* **MODERATE PAUSE** ...

## 5. **PRECISION POWER --- PRECISION TRIM --- COWL FLAPS**

\*\*\*\*\* **LONG PAUSE** ...

## 6. **COMMAND DECISIONS** - i.e. heights, divert or continue, A.T.C. etc.

\*\*\*\*\* **WHEN READY** ... (assuming that the situation allows)

## 7. **VISUALLY IDENTIFY THE PROPELLER FEATHERED AND SAY ALOUD YOUR ACTIONS e.g.**

CONFIRM - LEFT PROPELLER FEATHERED

LEFT Fuel	-	OFF	
LEFT Boost Pump	-	OFF	
LEFT Ignition	-	OFF	(the order will depend on cockpit layout)
LEFT Generator	-	OFF	

\*\*\*\*\* **FURTHER PAUSE** ...

## 8. **FINAL CHECK**

Check Powers - Engine Instruments - Suction - Reduce Electrical Loads - Fuel Management - Review Operational Decisions etc. i.e. General Final Check of all items.

Note: The above Engine Failure procedures relate to SINGLE PILOT operations and assume continued flight is possible.

For TWO PILOT operations the only difference is that the "CHALLENGE and RESPONSE" system is utilised

Items 1-6 of the Check List are Phase 1 Items and must be memorised **PRIOR** to commencing any asymmetric training. Items 7-8 need only be completed provided time is available (these items should also be memorised, with the Engine Failure Check List being used for confirmation).

Elimination of aerodynamic slip (if necessary) should only be considered **AFTER** Items 1-5 have been completed - (see DEFINITION SECTION - AERODYNAMIC SLIP).

Whilst engine fire has not been covered, the same Check List can also be adopted for such a situation.

Again with an **OBVIOUS** engine failure there are times when the propeller may need to be immediately feathered. As with engine fire, this will be explained in greater detail by your flight instructor.

## 12. HOW THE ASYMMETRIC TRAINING SEQUENCES SHOULD BE HANDLED

### AIR EXERCISE 1 - At height

This will consist of

- a/ Vmc(a) demonstration
- b/ Turns - propeller feathered, or zero thrust if no unfeathering accumulators

### AIR EXERCISE 2 - At height

Running out of fuel on the selected tank is to be simulated.

Demonstrate the correct method of changing tanks, emphasising the need to close the throttle before reintroducing fuel to the engine.

Show instrument indications.

When simulating this exercise, the pilot should complete Items 1, 2 and 3 of the Check List - he then "rectifies" the problem.

### AIR EXERCISE 3 - At height

Partial engine failure is introduced and, in this exercise, the pilot is shown continued flight with reduced power.

When simulating this exercise, Items 1, 2 and 3 of the Check List should be completed. (Use of power on the "problem" engine should be discussed).

### AIR EXERCISE 4 - At height

Following a partial engine failure, the exercise now shows the action when the pilot then finds it necessary to stop the engine and feather the propeller.

Check List Items 4 to 8 are therefore completed.

### AIR EXERCISE 5 - At height

The obvious engine failure - for this exercise, the pilot completes Check List Items 1 to 8.

The instructor, however, discusses the situation which may require immediate feathering of the propeller - (Items 2 and 3 would not be completed until after the propeller is feathered).

### AIR EXERCISE 6 - At height

An engine stops for no obvious reason - for this exercise, there could be two solutions i.e.

1. Rectification
2. A requirement to feather the propeller

In each case, Check List Items 1, 2 and 3 would be completed, then either rectification or Items 4 to 8.

**As can be seen, the initial asymmetric exercises are completed at height, and only when the pilot is considered sufficiently competent is the engine failure on take-off introduced.**

### AIR EXERCISE 7 - Engine failure following take-off

Initially, to be introduced at approx 400 ft by slowly closing the throttle.

Engine failure below 400 ft can be introduced after the trainee understands the various factors which provide justification for concessioning the 400 ft **DECISION HEIGHT**.

The importance of **DECISION** and **INITIAL CLIMB SPEEDS** should also highlighted.

Discuss the procedures for partial engine failure after take-off, as well as the obvious failure, and failure for no apparent reason.

Engine failure **AFTER** take-off should be treated with respect, as an emergency is being created, hence the need for a thorough briefing by the instructor to ensure there can be no misunderstandings. In fact during any asymmetric exercises, both instructor and trainee must know what the particular exercise will entail, and what is expected of both parties.

As far as engine failure **DURING** take-off is concerned, (i.e. before the aeroplane leaves the ground), this exercise should also be approached with caution, as there is the possibility of a nose wheel being damaged through the subsequent yaw, which can result when simulating the engine failure.

### AIR EXERCISE 8 - Engine failure on base or final approach

The procedures should be discussed and an air exercise completed.



### GENERAL COMMENTS

1. For engine failures in training, such catch phrases as "dead leg/dead engine, pressure left/feather right, the aeroplane points to the dead engine" can be used but, normally, a complete failure will be the result of a partial failure, or it will be an obvious failure, unless of course it is a case of running out of fuel on one tank in which case one of the "catch phrases" could be beneficial.
2. Zero thrust should be "set" only after the trainee completes the correct feathering checks.
3. When **RE-STARTING** an engine in flight, there will be less chance of making a mistake if the re-start procedure is called aloud e.g.

CONFIRMING	-	LEFT ENGINE TO BE STARTED
LEFT FUEL	-	ON
LEFT THROTTLE	-	SET
LEFT MIXTURE	-	RICH
etc etc		

4. During asymmetric training, if at any stage the aeroplane does not seem to be performing as it should, the likely reason will be that :
  - a. The gear or the flaps have not been retracted
  - b. The mixture control is still in the "cut-off" position
  - c. The fuel selector is in an incorrect position

So ends our discussion on engine failures and asymmetric flight - whilst some of the information and suggestions offered in this section may conflict with techniques currently being taught, this is because too many of those techniques are wrong. No doubt there will also be statements in this book which you may find hard to interpret - if this be the case, the instructor completing your endorsement training is the person to see.

\*\*\*\*\*

The modern aeroplane is one of the safest forms of transport - anyone can learn to fly an aeroplane, but to be a good pilot requires more than manipulative skill. It is also essential to have the ability to make **RESPONSIBLE COMMAND DECISIONS**, and to appreciate what the aeroplane **CAN** and **CANNOT DO**.

Hopefully, the extra knowledge gained in reading this book will improve the safety record of the light twin engine aeroplane and result in better, safer, and more competent twin engine pilots.

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