# STUDENT STUDY GUIDE

# VOLUME 4

# TWIN ENGINE PHASE

# EDITION 4

CONTENTS

<u>Amendments</u>

Chapter 4, Section 1 “e” Last sentence “For the PA 34 this height is ~~300~~ 200 feet AGL” *I Deabill 10 Jan 06*

Chapter 4, Section 2 , “The asymmetric committal height is ~~300~~ 200 feet QFE” (This version this change was complete) *I Deabill 10 Jan 06*

Rewrite Chapter 4 *N McMillan 21 Feb 07*

Typing corrections Chapter 4 *N McMillan 10 May 07*

New Logo added, I Deabill 24 Sept 08

# CHAPTER 1

# CONVERSION TO TWIN ENGINED AIRCRAFT

## General Handling

The pre-flight briefing will include:

(a) Expanded Check List, Flight Operating Procedures and Technical Notes.

(b) Cabin Layout, instrumentation and switches.

(c) Taxiing and Power Checks.

(d) Take-off Technique.

(e) Engine handling, including synchronisation.

(f) Straight and Level flight at various airspeeds.

(g) Stalling

(h) Steep Turns.

(i) Descending

(j) Approach and Landing.

(k) Going around.

During the pre-flight briefing the differences in handling between single and twin engined aircraft will be highlighted.

## Air Exercise

1. **External and Internal Inspection.** Your instructor will allow you initially to use the Expanded Check List but the Aircraft Check List should be used subsequently.

2. **Engine Starting.** The left engine is normally started first, following Check List instructions.

**Note:** (i) Instruction will be given on the procedure for starting if the engine becomes over-primed.

(ii) As soon as the engine starts, you should adjust the throttle to avoid an excessive burst of power.

3. **Taxiing.** The general principles you learnt on the single apply equally to the twin. The aircraft is manoeuvred using nosewheel steering, but differential power and wheel brakes may be used if the circumstances require it. Carry out taxiing checks per check list.

4. **Take-off and Climb.** Line up on the runway. Open up both throttles to 2000 rpm against the brakes. Carry out the runway checks, release the brakes and apply take-off power (35" MP - overboost lights out). Check RPM (See Aircraft Check List). Directional control is achieved with the steerable nosewheel and the rudder.

Rotate the aircraft at 77 knots at all weights, and when a safe height has been reached, brake the wheels and retract the undercarriage. Maintain a shallow climb until 100 knots is reached and then raise the nose slightly, reducing RPM to 2400 which will reduce the MAP to 34". Note the climbing attitude. In a prolonged climb the manifold pressure will gradually decrease, and the throttles should therefore be adjusted from time to time to maintain 34". Carry out climb checks per Check List.

**Note:** The rotate speed of 77 knots coincides with V2, (See Chapter 2 Para 9) ensuring that in the event of engine failure a sufficient margin of control will be available immediately the aircraft has left the ground.

5. **Flight at Various Speeds**

**(a)** **Cruising Speed.** Levelling off from the climb should be started about 50' below the height required and the speed increased to 140 knots. At 135kts reduce RPM to 2200; when speed stabilises adjust MAP to approximately 30" or as required to maintain 140kts. Set cruising power in range 28" - 32" MAP and 2200 rpm. Carry out the cruise checks using the Check List and note the attitude and the effectiveness of the controls and trimmers.

Your instructor will ask you to do Rate 1 Medium Turns, and then Steep Turns up to 45° bank. Note the attitude and the slight reduction of IAS during the steep turns. Additional power is not normally required.

**Note:** A steep turn carried out for avoiding action with the aircraft in the holding or landing configuration would, of course, require application of power.

**(b)** **Holding Speed.** You will be asked to carry out the initial approach checks from the Check List, and with the throttle set to 21/22" MP the speed will reduce to 115 knots. Note the change in the level attitude, and the effectiveness of the controls. 115 knots is the speed used for flying the hold, instrument pattern and for commencing the downwind leg of the visual circuit.

You will be asked to carry out Rate 1 level turns, straight descents, and descending turns at Rate 1. Note the attitude and power required for the descent at 115kts (15" should give approximately 600fpm rate of descent).

In this configuration it is important to set the power for level flight coincidentally with achieving the airspeed required. In levelling off from a descent, for example, if the power is set correctly but at an airspeed much below 115 knots, the airspeed will be very slow to recover, and may not do so if a turn is commenced after the level off.

**(c)** **Gear and Flaps Extended.** Carry out the pre landing checks and note the transient trim change as the gear is lowered. Note the gear and flap limiting speeds, lower flap to 25° and note the adjustment of power required to maintain level flight at 100 knots (24" -25" MAP). Note the attitude for level flight and the slightly reduced effectiveness of the controls. Carry out Rate 1 level turns, straight descent and Rate 1 descending turns as before, noting attitude and power setting (15" MAP approx) to maintain a minimum of 500 fpm.

Finally, lower full flap and simulate the final approach at 85 knots. At a suitable height initiate a go-around by applying full power (35"- 40" MAP) and after rotation to the climbing attitude, raise the flaps to 25°, then with a positive rate of climb raise the gear, climb at 90 knots, then raise the flaps fully 200ft from go around height and once the gear has fully retracted and continue the climb at 100 knots, 34" MAP 2400 rpm.

You will be asked to climb to a suitable altitude for stalling; level off and maintain 115 knots. (21/22" MAP)

6. **Stalling**

**(a)** **Pre Stall Checks.** The HASELL checks are as for the single engined aircraft except that A - Airframe must include "undercarriage as required". The rpm should be set to 2400, thus allowing 40" MAP to be used. Ensure that the mixture is rich.

**(b)** **Clean Stall.** Close both throttles and maintain level flight, keeping straight with gentle applications of rudder until the stall is reached with the control wheel fully back. As the nose attitude is adjusted the elevator may be trimmed, but not below 100 knots. Note the airspeeds at which the stall warning horn operates, the buffet commences and the full stall occurs.

**Recovery (with minimum height loss)**

! Control wheel forward sufficiently to unstall the wings, ailerons neutral.

! Both throttles to full power (35-40" MAP) - BEWARE OF OVERBOOSTING

! Rudder to prevent further yaw.

! Level the wings with aileron when airspeed sufficient.

! Ease out of the dive and select the climbing attitude

**(c)** **Approach Configuration.**

**(i)** **<u>Base turn</u>**. Select gear and flaps 25° and 15" MAP and commence a “simulated” base turn (30° max AOB min 10° AOB). Maintain level flight until the stall warning or light buffet occurs. Apply full throttle (35-40" MAP – avoid overboost) and maintain the pitch attitude with forward pressure on the control wheel. Once stall indications have ceased roll wings level, raise the flaps to 25°, then with a positive rate of climb raise the gear, climb at 90 knots, then raise the flaps fully 200ft from go around height and once the gear has fully retracted and continue the climb at 100 knots, 34" MAP 2400 rpm.

**(ii)** **<u>Final.</u>** Fly “simulated” circuit to end up on final, gear down, full flap, trimmed at 85kts and with 15" MAP set. Start to stretch the approach until the stall warning or light buffet occurs. . Apply full throttle (35-40" MAP – avoid overboost) and maintain the pitch attitude with forward pressure on the control wheel. Raise the flap to 25°, then with a positive rate of climb raise the gear, climb at 90 knots, then raise the flaps fully 200ft from go around height and once the gear has fully retracted and continue the climb at 100 knots, 34" MAP 2400 rpm.

7. **Circuit Procedures**

**(a) The Circuit Pattern.** The normal circuit is of the oval race-track pattern . A square circuit may be flown to accommodate other traffic (Appendix A).

**(b) Circuit Speeds.**

(i) With 21/22" MP, the circuit speed will be 115 knots

(ii) Abeam the threshold, carry out the pre-landing checks per the Check List (check gear and flap limiting speeds, selecting gear and 25°),start the stopwatch, set 15" MAP and commence descent(1) at 100 knots. After 25-35 seconds, depending on wind strength, commence a continuous descending turn onto the final approach, speed 90-100kts. Halfway round the turn select full flap and allow the speed to reduce to 85kts. During the turn, before the R/T call, carry out the Final Check per the Check List. The power setting and timing should be consistent with circuit conditions, but in all cases the descent downwind should not be continued below 1000' agl

(iii) On final, the aircraft should be stable and trimmed at 85kts with gear down and full flap. The wings should be level by 400' agl. It is important to keep the aircraft trimmed during the approach to avoid high control wheel loads during the round out and landing.

NB (1) The descent downwind is only carried out if the circuit height is more than 1000ft agl.

8. **Landing.** The correct VAT, calculated for fuel load and persons on board, is given in the Expanded Check List. The throttles should be closed together during the roundout and the control wheel brought back progressively until the main wheels contact the runway. The back pressure required is high.

**Note:** (i) **CAUTION -** Pushing the control wheel forward following a bounce on landing may lead to "porpoising", with the possibility of the propeller tips striking the ground.

(ii) A common fault, due to the undercarriage geometry, is failing to continue the roundout sufficiently to achieve the landing attitude.

(iii) Landings at MAUW are in emergency only. The normal maximum landing weight is 4340 pounds.

The demonstrated crosswind component for the PA34 is 17 knots. Maximum crosswind components as laid down in the Operations Manual (Training) must be observed for training flights.

The "crab" technique should be used. In conditions of strong gusty crosswind the initial approach speed should be 90 knots and the threshold speed increased by about 5 knots. Eliminate drift before touchdown. On the runway, full into-wind aileron may be required if the crosswind is near to the limit.

**Note:** The wing down technique for eliminating drift is not used at OATS.

For a flapless landing the initial approach speed should be 90 knots. The threshold speed must be increased by 5 knots.

**Note:** (i) On the approach, the aircraft has a higher nose attitude compared with the flapped approach.

(ii) During the final stages of the approach the aircraft is nearly in the landing attitude, and therefore only a small roundout is required.

(iii) The period of float before touchdown may be longer; roundout should therefore be initiated at the runway threshold.

9. **Touch and Go.** After touchdown, select flap up, reset the trimmers and apply take-off power (35" MP). Rotate at 77 knots and continue as for normal take-off.

10 **Going Around.** The technique is as follows:

(i) Level the wings.

(ii) Apply full power smoothly 35-40" MP). - BEWARE OF OVERBOOSTING and select the climbing attitude

(iii) Select flap to 25° and then with a positive ROC select Gear Up.

(iv) Climb at 90 knots.

(v) Above 200' AGL raise the remainder of the flap.

(vi) Keep straight.

(vii) When IAS reaches 100 knots, reduce power to 34" MP and check rpm are 2400.

## CHAPTER 2

## ASYMMETRIC PROCEDURES

1. The condition of asymmetric flight occurs when the aircraft is flown with unbalanced thrust on either side of the plane of symmetry. This causes a yawing moment which is counteracted by the correct operation of the flying controls.

2. **Basic Considerations** Your instructor will explain the forces involved using a model aircraft.

When an engine fails, asymmetric thrust will cause yaw towards the failed engine. If this yaw is uncorrected, the aircraft will roll and the nose will drop. Since the yawing moment is the immediate problem, the first action of the pilot must be to keep straight i.e. stop yaw.

3. Yaw when an engine fails (or is stopped) is very marked, and its severity will depend on:

(i) The amount of thrust being delivered by the live engine.

(ii) The thrust moment arm.

(iii) The amount and moment of offset drag.

(iv) The indicated airspeed.

(v) Slipstream effect on the keel surface.

(vi) Asymmetric blade effect on the live engine.

4. The rudder is the primary control in preventing yaw, and its effectiveness is governed by:

(i) The indicated airspeed.

(ii) The angle of deflection.

(iii) The rudder moment arm - the distance between the rudder and the centre of gravity.

(iv) Aircraft directional stability.

(v) The strength and skill of the pilot.

The aircraft design characteristics, such as the size of the rudder and the effectiveness of the fin and rudder as an aerofoil in producing a side force when at an angle of attack to the relative airflow will also influence rudder effectiveness as will the amount of keel surface forward of the centre of gravity.

5. **Critical Speed.**
This is the lowest possible speed on a multi-engined aircraft at which, at a constant power setting and aircraft configuration, the pilot is able to maintain a constant heading after failure of one or more engines on one side.

6. **Factors Affecting Critical Speed** (summarised at the end of Chapter 5)
Critical Speed is not a "fixed" speed, being dependent on many factors. The more important are:

(i) **The power or thrust of the live engine.** The greater the power or thrust, the higher the critical speed. The yawing moment is directly proportional to the power or thrust of the live engine, so at a given IAS more rudder deflection is required to prevent yaw as power or thrust is increased. The power or thrust of the engine is affected by several factors (for example, altitude) but any factor which increased the engine output will raise the critical speed.

(ii) **The position of the centre of gravity.** The yawing moments act around the centre of gravity and if the centre of gravity is in a forward position the rudder moment arm will be longer and the rudder more effective. Similarly, an aft centre of gravity position will reduce rudder effectiveness and thus raise the critical speed.

(iii) **Asymmetric Drag.** Any increase of drag on the same side as the failed engine will increase the yawing moment, thus raising the critical speed. Any actions that can be taken to reduce the asymmetric drag will improve the situation. These will include feathering the wind-milling propeller and selecting cooling flaps and shutters to the minimum drag position. On some aircraft types there may be asymmetric aileron drag.

(iv) **Bank towards the live engine.** This will reduce the critical speed, and only very small amounts of bank are effective. There are, however, dangers and difficulties associated with this, and the general considerations (Chapter 5) should be noted.

(v) **Position of the wing flaps and undercarriage.** The position of the flaps may have a marked effect on the airflow over the tail surfaces. This effect varies between aircraft types and any significant details are included in the Flight Manual. The flaps and undercarriage in the down position will increase the total drag, necessitating an increase in power or thrust with the adverse effect noted in sub para (i).

(vi) **Slipstream.** The slipstream from the individual propellers may strike the fin and rudder at different angles, particularly if the propellers are rotating in the same direction, tending to produce in the one case a side force from the fin which acts to assist the rudder side force needed to counteract the yawing moment, whilst the other slipstream may produce a fin side force acting in opposition to the rudder side force. Failure of the first engine would therefore result in a more critical situation than failure of the second, and a higher critical speed. The rolling moment due to loss of slipstream on one side (Chapter 4 para 7) is normally corrected with aileron, but the use of aileron will mean more drag.

(vii) **Asymmetric blade effect.** At the high angles of attack associated with low airspeed, the propeller disc is tilted in relation to the relative airflow, and the down going blade will produce more thrust than the upgoing blade; the point through which the thrust acts will be displaced towards the down going blade. Depending on the direction of rotation of the propeller, this either increases or decreases the thrust moment arm, and in aircraft with the propellers rotating in the same direction, failure of the engine with the shortest moment arm will produce the greatest yawing moment (from the other engine). The engine with the shortest moment arm is known as the Critical Engine, and it is on this engine failure that minimum control speed will be based.
The use of engines with propellers rotating in opposite directions obviates this difficulty, and if the propellers rotate inwards towards the fuselage the moment arm will be kept as short as possible with a consequent reduction of critical speed.

(viii) **Turbulence.** On a day with rough and gusty conditions the margin of control is reduced. If the rudder is almost fully over in one direction, a very limited amount of movement is available for corrections necessitated by turbulence. This in effect increases the critical speed.

(ix) **Altitude and Temperature.** The greater the altitude and temperature, the less thrust the engine will produce and therefore the critical speed will be lower. The general performance will be reduced.

(x) **Rudder Trim.** If a pilot is unable to apply full rudder because of insufficient strength, the use of rudder trim will reduce footloads and thus facilitate rudder application, but it should be noted that a normal rudder trim tab acts by being deflected in the opposite direction to rudder deflection, and it thus decreases rudder effectiveness. In the case where the pilot is able to apply full rudder, the use of rudder trim will therefore increase the critical speed slightly.

(xi) **Strength and skill of the pilot.** The footloads required to fly an aircraft at high asymmetric power or thrust when at a low IAS are often very high, and the physical strength and leg length of the pilot may determine whether or not full rudder can be applied. The use of less than full rudder in these circumstances leads to a higher critical speed and the erosion of safety margins. The correct adjustment of the pilots seat is therefore important.

A skilful pilot may be able to give more attention to controlling the aircraft directionally than a less experienced pilot who may be distracted by other actions. Confidence in handling engine failures competently arises from regular practice.

If at any time the speed falls below the critical speed, the primary consideration is to keep straight at all costs. If the pilot cannot do this using the flying controls, he must reduce power sufficiently on the live engine to stop the yaw. Height may be lost, but this must be of secondary importance to keeping straight.

7. **Minimum Single Engine Control Speed ($V_{MCA}$):** PA34 - 68 knots
The take-off minimum control speed in free air. The minimum speed at which, if sudden complete failure of the critical power unit occurs during the take-off climb out, it is possible to regain control and thereafter maintain straight steady flight at the same speed. The change of heading should not exceed 20° and the final angle of bank should not exceed 5°.

8. **Refusal Speed ($V_I$)**
This defines the decision point during a take-off, and before which the take-off can be discontinued. It is the maximum speed for a given length of take-off distance available from which the aircraft could be brought to rest in the remaining length of surface using maximum (non-skid) braking applied not more than five seconds after one engine has failed. Dry and wet runway values are given.

**Note:** No refusal speed is quoted for the PA34, but the following extract is from the British Flight Manual for the type:

*"The action taken after the failure of one engine during the take-off depends on available stopping distance or the ability to clear or avoid all obstacles under single engine operation. In all cases where the speed is below 77 knots the throttle should be closed and the aircraft brought to rest."*

9. **Take-off Safety speed ($V_2$):** PA34 - 77 knots.
The minimum speed at which, following sudden and complete failure of an engine at take-off power, with the aircraft in the take-off configuration, a safe margin of control is available, above the stall, to the average pilot.

**Note:** (i) The PA34 is included in Performance Group B (JAR), which includes aircraft with a performance such that a forced landing should not be necessary if a power unit fails after take-off and initial climb has commenced with the undercarriage retracted.

(ii) The rotation speed for the PA34 is the same as $V_2$. This means that a safe margin of control is available immediately the aircraft has left the ground on take-off. This does not mean, however, that the take-off will be automatically continued.

10. **Engine Failure on Take-off (PA34).**
There are three phases during the take-off process which must be considered in relation to engine

failure.

(a) Aircraft Speed less than Take-off Safety Speed $V_2$

In the event of an engine failure below take-off safety speed (PA34 77 knots) both throttles must be closed, the aircraft kept straight and the take-off abandoned.

(b) Aircraft Speed between $V_2$ and Single Engine Climb Speed (PA34 - 89 knots).

The decision to abandon or continue the take-off will depend on a number of factors, the more important being:

(i) Degree of engine failure (partial or complete power loss, or fire)

(ii) Whether the failed engine propeller has feathered.

(iii) Speed attained at the time of engine failure.

(iv) Aircraft weight, airfield elevation and temperature.

(v) Aircraft configuration.

(vi) Length of runway remaining.

(vii) Position of any obstacles, and slope of the ground ahead.

In the light of these factors, it may be necessary to carry out a forced landing using the power from the live engine to manoeuvre the aircraft to a suitable area.

(c) Aircraft speed at or above Single Engine Climb Speed, carry out the Engine Failure After Take-off drill.

If immediate action is applied, it should be possible to climb away in a normally loaded aircraft, providing obstacles and terrain slope permit. Full power will be required on the live engine.

**Note:** When practising engine failure after take-off in the circuit, your instructor will simulate the failure by smoothly closing the throttle at a height of not less than 400 feet agl, and at a speed of not less than 77 knots (PA34).

11. **Engine Failure on Take-off Drill (PA34)**

(a) If an engine failure occurs after take-off, it is vital that the drill is accomplished rapidly and accurately. Speed of reaction to either visual or instrument indications can be improved only with regular practice, and it should be appreciated that failure to react immediately to control the situation can very quickly lead to a complete loss of control close to the ground.

If the IAS is maintained at or above the Take-off Safety Speed the aim should be to keep the aircraft straight with the slip ball centred and the wings level; this should present little difficulty. However, after the failed engine has been identified, it is permissible to apply up to 5° of bank toward the live engine if this is found to be necessary.

(i) Stop the yaw by instant use of rudder. If the wings are level the slip ball must be in the centre. Lower the nose to maintain at least Take-off Safety Speed ($V_2$).

(ii) Identify the failed engine.

(iii) Apply full power to the live engine.

(iv) Feather the propeller on the failed engine. (For practice purposes this will be simulated using a "touch drill" procedure, and your instructor will simulate the drag of the failed engine by setting the propeller to the zero thrust position [14" MP]).

(v) Undercarriage up.

(vi) Flap Up

(vii) On the failed engine switch off:

Magnetos )
Fuel Pump ) (For practice purposes use the "touch drill"
Fuel Cock ) procedure.)

(viii) Check for FIRE. Make a visual check of the failed engine for signs of fire.

(ix) On the live engine check:

Temperatures and pressures.

Cowl flap positions. Close the cowl flap on the failed engine and adjust that on the live engine to control cylinder head temperature.

Alternator output. Make sure that the load does not exceed 60 amps. Switch off non-essential equipment if the load is high i.e. above 50 amps.

Gyro pressure. Check that there is sufficient pressure for the correct operation of the artificial horizon.

(x) RT Call. (MAYDAY or PAN). If everything is under control a PAN call will suffice. However, if there is evidence of fire or some other major problem, (e.g. the live engine is faulty) a MAYDAY call should be transmitted.

(xi) Trim - as required.

(b) It is important to understand that after the failed engine has been identified, power should never be applied to the live engine without due consideration of the consequences. In the engine failure after take-off drills, full power is applied to the live engine, but the assumption is made that the IAS is at least $V_2$ (77 knots PA34). It follows therefore that a positive check must be made that both airspeed and rudder control are satisfactory before power is applied, in the knowledge that if the airspeed is between $V_2$ and $V_{MCA}$, directional control will be difficult, and below $V_{MCA}$ directional control will be lost.

# CHAPTER 3

# ASYMMETRIC AIR EXERCISES

## ASYMMETRIC FLIGHT (PART 1)

1. The aim of this exercise is to teach you:

(a) To recognise the symptoms of an engine failure.

(b) How to control the aircraft following an engine failure.

(c) How to identify which engine has failed.

(d) The effects of power and speed on control available under asymmetric power.

The air exercise will be carried out in the following sequence:

2. **Single Engine Flight**

(a) At a suitable height above 3000 feet agl and within easy reach of a suitable airfield, you will be shown how to carry out a feathering drill using the Check List. You will be asked to carry out normal manoeuvres and you will see:

(i) That the handling characteristics of the aircraft during Rate 1 turns in either direction presents no particular problems.

(ii) The power required for straight and level flight at 110 knots is 32"-34"/2400 rpm.

(iii) The rudder pedal displacement and rudder trim required.

(iv) The ball of the T.C. should be central.

(v) The engine instrument indications and rapidity of cooling of the stopped engine.

Fuel crossfeeding will be demonstrated.

(b) Unfeathering is done from the Check List.

(i) Set 14" MAP for warm up and note that the rudder pedal displacement and trim requirement is the same as for the feathered condition. (At the same IAS).

(ii) Normal two engined cruise can be resumed when temperatures and pressures permit.

3. **Effect of Engine Failure**

At normal cruising speed, trimmed for straight and level flight, your instructor will throttle back each engine in turn to show you:

i) By external reference how the aircraft will yaw, roll and spiral toward the failed engine.
(ii) The flight instrument indications - especially the reaction of the slip ball, which will shoot out towards the rudder which is required to stop the yaw.

4. **Action to Maintain Control**

From normal straight and level flight your instructor will throttle back one engine and demonstrate the action necessary to maintain control:

(i) Prevent yaw with rudder. The slip ball centred.

(ii) Use aileron to keep the wings level.

(iii) Maintain height with elevator. (A loss of airspeed is acceptable at this stage in the cruise).

The slip ball must be in the centre for balanced flight with wings level.

You will then practise the control technique both by external visual reference and by reference solely to the flight instruments.

5. **Identification of Failed Engine**

(a) It is vital that the failed engine be rapidly and correctly identified because all subsequent drills depend upon you knowing which engine has failed and which engine is live, and in some circumstances of engine failure, time may be short. You will be shown the "DEAD LEG - DEAD ENGINE" method of diagnosis. If you are pushing on one rudder pedal to prevent yaw, the other leg will be doing nothing, and is therefore "DEAD". Your "DEAD leg is situated on the same side as the "DEAD" or failed engine, and so to identify the "DEAD" engine you call out - "left (or right) leg dead, left (or right) engine dead".

(b) Your instructor will mask the throttle quadrant whilst simulating failures to give you practice in both control and identification.

(c) You will also be shown the alternative method of maintaining directional control after engine failure, i.e. close both throttles, noting:

  (i) The yaw is stopped and control easily regained, but loss of height and/or speed is considerable; this method may not therefore be acceptable, but it is relevant to the engine failure on take-off case when throttling back the "live" engine may be necessary in order to maintain directional control.

6. **Effect of Engine Failure in Turns**

(a) At normal cruising power you will carry out a 30° bank level turn, and the inside engine will be throttled back. The rate of roll and the steep spiral condition will rapidly develop if no corrective action is taken.

(b) The turn is repeated and the outside engine throttled back. The roll development is slower, which allows more time for corrective action, but again, if no corrective action is taken, the aircraft will enter a spiral toward the failed engine.

(c) You will be shown the instrument indications of an engine failure during turns, and also how to control the aircraft - prevent yaw with rudder, then level the wings and identify the failed engine.

You should make a practice of calling which engine has failed each time a failure is simulated.

7. **Effect of Varying Speed at a Constant Power Setting**

(a) With the power set at about 22" MAP and 2400 rpm, and the aircraft trimmed to fly straight and level, your instructor will throttle back one engine; maintain directional control (with the rudder trim neutral) and hold the speed at 120 knots, disregarding height. He will ask you to:

(i) Check heading and ball central for straight balanced flight. Check that the wings are level.

(ii) Note rudder displacement and footload required.

(b) He will then allow the speed to reduce to 100 knots where you will be able to see:

(i) The increased rudder displacement and additional footload required to maintain direction and balance as the speed decreases. The ball must be kept in the centre and the wings level.

8. **Effect of Varying Power at a Constant Speed**

Maintaining 120 knots as above, your instructor will decrease and increase power in stages. Maintain straight balanced flight. With a reduction in power a decrease of rudder displacement and footload will be required, and with an increase in power an increase of rudder displacement and footload will be required.

Changes in airspeed and power result in changes of rudder requirement to keep straight. The critical combination is high power, low speed.

**Note:** During these exercises (paras 7 and 8) the maintenance of reasonably accurate airspeeds is important to the aim of clearly understanding the effects of speed and power. To this end, during your practise your instructor may control the power, pitch and roll, whilst you control the rudder.

## ASYMMETRIC FLIGHT (PART 2)

1. Your aim during this exercise is to:

(a) Learn the significance of critical speeds.

(b) Learn and practise the engine failure after take-off (EFATO) drill.

(c) Practise the feathering and unfeathering drills.

2. As discussed in Chapter 2 paras 5 and 6, critical speed is a variable figure which depends upon many factors, but here you will be shown only three variations, chosen for their importance and practicality. The exercise could be flown with any desired amount of power on the live engine, but since we are concerned with the worst possible case, full power is used.

The exercise is not convincing if carried out at too great an altitude. 2000 feet agl is a reasonable height.

3. **Determination of Critical Speed (Full Power)**

(a) **Wings level, throttle closed, clean aircraft.**

(i) With maximum rpm set on both engines at a speed of about 120 knots, one throttle will be closed. Full throttle (40" MAP PA34T) will be set on the other engine and directional control maintained with the wings level and the ball central.

(ii) Speed will then be reduced keeping the wings level and the ball in the centre until directional control is lost; i.e. the ball departs from the centre and the aircraft yaws, with full rudder applied. Refer to the gyro compass as an aid to direction. Note the critical speed.

**Note:** The Critical Speed under these conditions is very close to the stall, so if the stall warning horn sounds, recovery must be effected at that point. This should not, however, prevent the determination of the critical speed, which is above the stalling speed.

(iii) The recovery from this condition is to throttle back the live engine and lower the nose to increase speed until directional control is regained.

(b) **The effect of up to 5° bank towards the live engine.**

In the same configuration as at (a), the speed is held at 80 knots. (A convenient datum speed). If then up to 5° of bank is applied towards the live engine, the aircraft will turn. It follows, therefore, that in order to maintain a constant direction, the amount of applied rudder must be reduced. The ball will now be offset slightly towards the lower wing.

Less rudder now being required to keep straight, it follows that with the bank applied, and with full rudder, a lower critical speed could be achieved than that found in the first part of the exercise. However, we do not practise going to the lower critical speed because that would take the aircraft closer to the stall, which would be unwise under asymmetric power.

(c) **The effect of feathering.**

Holding the aircraft at 80 knots, one throttle closed, wings level and full power on the live engine as before, the simulated feather setting (14" MAP PA34) will then be set on the "failed" engine. The aircraft will turn, and so in order to maintain a constant direction, the amount of applied rudder must be reduced.

Less rudder now being required to keep straight, it follows that with the propeller feathered, a lower critical speed could be achieved.

To sum up, the lowest critical speed will be achieved with full rudder and not more than 5° of bank towards the live engine, with the propeller feathered on the failed engine.

Having completed this series of exercises, it should be clear to you that provided the airspeed is maintained at the Take-off Safety Speed ($V_2$) - 77 knots PA34 - or above, it will not be necessary to use bank in order to assist in keeping straight, although the option of using up to 5° of bank is always available.

4. **Engine Failure in the Take-off Configuration**

At a suitable height (1500 - 2000 feet), maximum rpm will be selected on both engines, the undercarriage selected down, 25° flap selected and the aircraft established in the climb at 77 knots with full power. Then:

(i) The throttle on one engine will be closed.

(ii) Note that it will be possible to maintain a constant direction, although height may have to be lost in order to maintain the speed at or above $V_2$ (77 knots).

(iii) Your instructor will show you how to carry out the flight procedure for engine failure after take-off. He will show you how, following each stage of the EFATO drill, the performance of the aircraft improves.

5. **EFATO Drill**

(i) Keep straight by instant use of up to full rudder, and up to 5° of bank (if required). Lower the nose to maintain IAS at or above $V_2$ (77 knots). (ii) Identify failed engine.

(iii) Full power on the live engine.

(iv) Feather failed engine.

(v) Raise undercarriage.

(vi) Raise flap.

(vii) On failed engine, switch off:

Magnetos
Fuel Pump
Fuel Selector
Cowl Flap Closed

(viii) Check for fire.

(ix) On live engine check:

Engine Temperature and Pressures
Cowl Flap position.
Alternator Output.
Gyro Pressure.

(x) R/T Call - PAN PAN or MAYDAY

(xi) Trim

**Note:** For practise purposes "touch" drills will be used in relation to the "failed" engine. Your instructor will set zero thrust as you touch the appropriate lever.

6. The PA34 is included in aircraft performance Category B. This means that following an engine failure after take-off, it should be possible to climb away after safety speed has been reached and the best single engine rate of climb speed (89 knots) established thereafter, provided the correct drills have been carried out. However, the aircraft may not be able to achieve a climb in conditions of high weight, altitude and temperature, and in addition, a forced landing may also be necessary if obstacle or terrain clearance cannot be achieved. Under these circumstances the live engine can be used to adjust the approach to the chosen landing area.

If the aircraft cannot be kept straight following an engine failure by using full rudder and 5° of bank toward the live engine then a reduction of power must be made to regain directional control.

The EFATO drill must be memorised.

7. **Feathering/Unfeathering Drills**

The final part in the air exercise will consist of practice feathering and unfeathering above a height of 3000 feet agl, and within easy reach of a useable airfield. The drills will generally be done after a simulated engine fire.

## CHAPTER 4

## ASYMMETRIC CIRCUIT (See Appendix B)

1. The following points will be made during the pre-flight briefing:

(a) The size and shape of the circuit pattern should be the same as the normal circuit except that the into wind climb will cover more ground.

(b) Undercarriage lowering should be abeam the touchdown point as normal but 25° flap should be delayed until halfway round the base turn.

(c) The rudder trim should be used to ease footloads.

(d) When practising asymmetric circuits, too large a pattern can cause difficulty due to the greater amount of power on final, and the danger of getting substantially below the approach path will be stressed. Too close a circuit, leading to a high position on final, and a glide approach, is as undesirable under asymmetric conditions as in a normal approach. The aim should be to fly the approach path at the correct angle and airspeed using a moderate amount of power as required within reasonable limits, without control difficulties.

(e) Your instructor will stress the importance of maintaining the correct approach speed (until a positive decision to land has been made). The airspeed is maintained at 90 knots (PA34) on the final approach until the asymmetric committal height is reached. For the PA34 this height is 200 feet agl.

(f) It is important to keep the aircraft in balance. For each change of power there will be a change of footload required to keep the ball central.

2. **Asymmetric Committal Height.** This is the height at which during an asymmetric approach a go-around must be initiated, unless all of the following criteria are satisfied:

(a) Clearance to land has been received.

(b) The runway is clear.

(c) The approach is satisfactory in all respects.

The Asymmetric Committal Height is normally 200 feet QFE (PA34). If the decision is made to continue the approach, it is at or after this point that full flap may be lowered. Full flap must not be lowered if a go-around is to be made. The airspeed is reduced to threshold speed after the Asymmetric Committal Height has been passed.

3. **The Go Around.** The following points will be emphasised:

(a) The wings must be level.

(b) Full throttle (40" MAP PA34T) should be applied smoothly and the rudder applied simultaneously to prevent yaw. For normal purposes 2400 rpm (PA34T) will suffice but maximum rpm may be applied if required. Check that the ball is central.

(c) As soon as full power is applied, raise the undercarriage and select flap up, holding the attitude.

(d) The footload required will be high.

(e) Ensure that the climbing speed of 90 knots is maintained. If necessary, a little height can be lost to achieve this. The airspeed must not be allowed to fall below the Take-off Safety Speed of 77 knots.

(f) The aircraft should be climbed straight ahead to 1000 feet agl if practicable.

(g) When circuit height has been reached, establish the circuit speed of 110 knots and reduce power to maintain.

4. **The Landing.** The pre flight briefing will include the following points:

(a) At asymmetric committal height the wings must be level, and the aircraft must be on the correct approach path i.e. the angle of approach must be correct and the aircraft aligned with the runway or intended landing path.

(b) Power from the live engine is used to regulate a normal descent path. The threshold speed is the same as for a two engine landing.

(c) If full flap is to be used for landing, allow it to take effect before adjusting power. You will be reminded that full flap must not be lowered above asymmetric committal height.

(d) Keep the rudder trimmed. This will assist when using power to regulate the descent, when changes of footload will be required as power changes are made.

(e) When the throttle of the live engine is closed during the roundout, the aircraft will yaw toward the live engine. A reverse footload will be required to prevent this. In crosswind conditions, this tendency to yaw will tend to either increase or reduce the drift angle, depending on the wind direction. Under these circumstances, prevent the yaw as the throttle is closed, then use the rudder in the normal way to align the aircraft before touchdown.

Note: ( i ) During practice asymmetric landings, the 14" MAP used to simulate a feathered propeller cannot be left on, because the lift derived from the slipstream may cause the wing to rise on that side. For landing, therefore, both throttles must be closed.

(ii) Speed should be adjusted on the approach to take turbulence into account as in a normal approach.

(iii) For a touch and go, rudder trim must be centralised and the flap selected up on the runway before applying full power on both engines. Normally you request your instructor to raise the flap and to centre the rudder trim. Confirm that both engines are delivering the correct power before continuing.

5. **After Landing.** When you are clear of the active runway, stop and carry out the after landing checks from the Check List.

# CHAPTER 5

# ASYMMETRIC FLIGHT - GENERAL CONSIDERATIONS

## Introduction

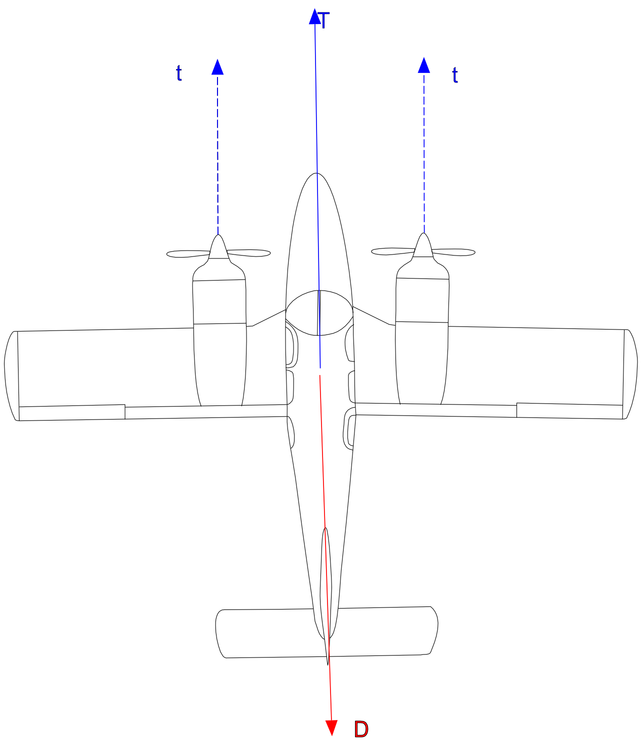
1. This Chapter is intended to expand in a general way the considerations discussed in the previous chapters.

2. The problems of asymmetric flight are associated with multi engined aircraft powered by engines which are displaced spanwise from the fuselage centreline. The problems are encountered in varying degrees by all aircraft with engine displaced in this way, whether they be wing, fuselage or tail mounted.

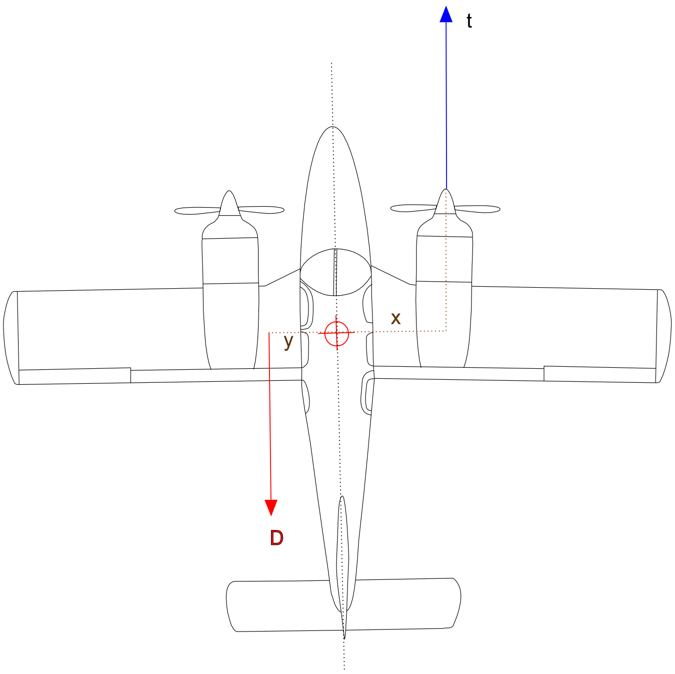
3. The handling techniques used for flight on asymmetric power are common to both jet and piston aircraft, and differ only in engine handling considerations. Specific information for individual types of aircraft is given in the Flight Manual, which must be consulted in detail before any asymmetric handling is undertaken.

## The Basic Problem

4. In normal flight, the thrust of both engines is equal and the total thrust (T) is the resultant of the two individual thrusts (t) (Fig. 1). The total thrust acts along the fuselage centreline. The total drag (D) is equal and opposite to the total thrust. The forces are balanced, so the aircraft has no tendency to yaw.



5. When an engine fails, the total thrust is halved and the thrust line is displaced, now acting through the position of the live engine. In addition, the drag of the failed engine is increased because of the extra drag caused by the windmilling or seized propeller (or compressor). This drag may also be increased still further by damaged cowlings in the case of severe mechanical failure. The total drag is therefore increased and displaced towards the failed engine. (Fig. 2).




6. The effect of the engine failure is therefore twofold;

(a) The thrust (t) acting through the moment arm (x), and the drag (D) acting through the moment arm (y) combine to cause the aircraft to yaw towards the failed engine.

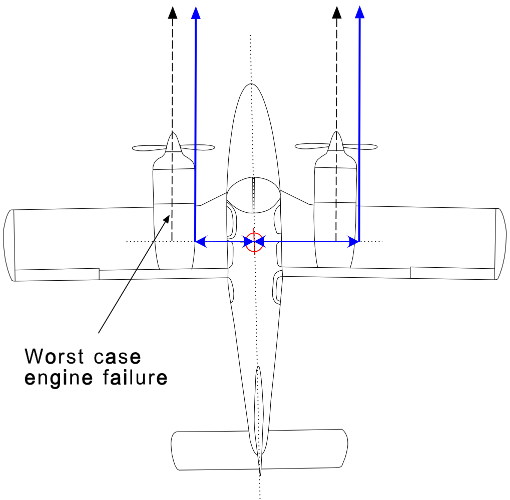
(b) Since the thrust has been reduced by half, and the drag increased, the aircraft will decelerate.

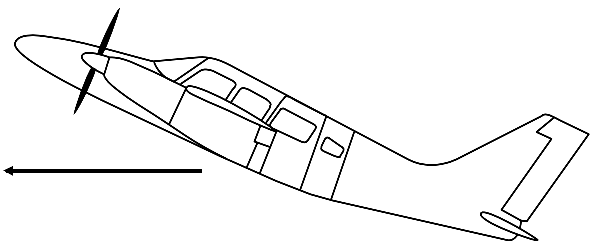
7. As shown above, when an engine fails, the thrust line will be displaced to one side of the aircraft centreline and a yawing moment is produced about the centre of gravity. This moment must be opposed by an equal yawing moment if the aircraft is to continue in a straight line. This correcting moment must also take into account the adverse yawing moment produced by the extra drag of the failed engine. It should be noted that this extra drag will be greater on a propeller engine. Additionally, with propeller aircraft there is a rolling moment caused by the loss of slipstream over a portion of the wing on the failed side, and possibly also a rolling moment due to (live engine) torque. If these yawing and rolling moments are not immediately opposed, the aircraft will rapidly yaw towards the failed engine, the further effect of yaw will add to any roll already present, and the aircraft will spiral dive. The yaw must be opposed. For equilibrium, all forces and moments must be in balance, and to achieve this, a side force must be produced to provide a correcting moment in yaw. Then all the resulting forces - thrust, drag, side forces - must be balanced out.

8. To continue in straight flight therefore, a yawing moment must be produced which is equal and opposite to the adverse yawing moment set up by the asymmetric thrust and drag. This requires a force acting at some distance from the centre of gravity. This force can be created by sideslip produced by rudder deflection, or by bank and slideslip produced by aileron deflection (but in this case, note the warning in para 15) or by a combination of the two.

9. **Adverse Yawing Moment.** The size of the adverse yawing moment depends mainly on the remaining thrust. The effective moment arm of the thrust, windmilling drag and its effective moment arm are important factors, and with propeller aircraft there may be further complications due to the loss of slipstream over the fin and rudder, and the yawing effect of applying aileron to counteract the roll due to loss of slipstream on the failed side. This may mean that failure of one particular engine has a greater adverse effect than failure of the other.

Another peculiarity of propeller aircraft (without counter-rotating propellers) occurs if the propeller disc is inclined at other than right angles to the line of flight as at low speed, when the differing angle of attack of the blades causes the centre of thrust to be offset (Asymmetric blade effect). This may change the yawing moment either adversely or favourably. (Fig. 3). It follows that in aircraft in which the propellers are rotating in the same direction there will be a "worse case" engine, with a shorter moment arm than the other and it will be the failure of this engine which is taken into account in the determination of critical speed.



10. **Corrective Yawing Moment.** The size of the yawing moment which is obtained to oppose the adverse yawing moment depends on the fin and rudder area, the amount of rudder deflection, the rudder moment arm (from the C of G), the equivalent airspeed, and the sideslip angle.

11. **Corrective Rolling Moment.** Where, in a propeller aircraft, there may an adverse rolling moment due to loss of slipstream and torque effects, the ailerons are normally powerful enough to provide an adequate corrective rolling moment except at very low speeds.

**Note:** Propeller torque tends to roll the aircraft in the opposite direction to that of propeller rotation and increases with power. Torque has a slight effect on the margin of control while using asymmetric power; if the torque reaction tends to lift the failed engine i.e. oppose the rolling moment due to sideslip, then its effect is beneficial.

12. **Methods of Maintaining Equilibrium.** There are three possible methods of achieving and maintaining equilibrium. These, in order of preference are:

(a) Wings level and sideslip towards the failed engine.

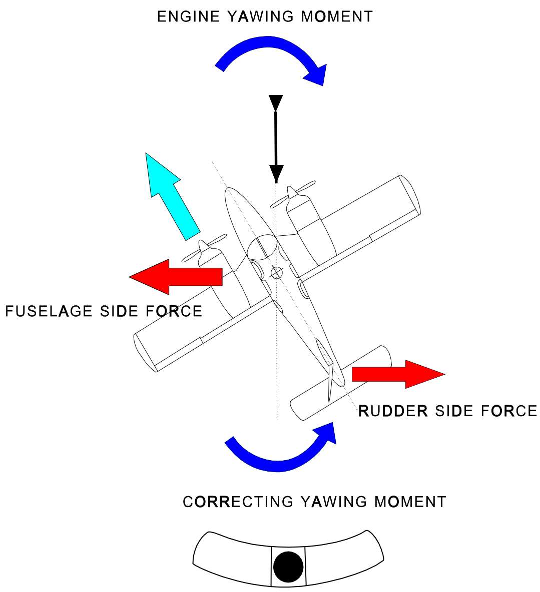
(b) Rudder and bank towards the live engine.

(c) Rudder central and bank and slideslip towards the live engine.

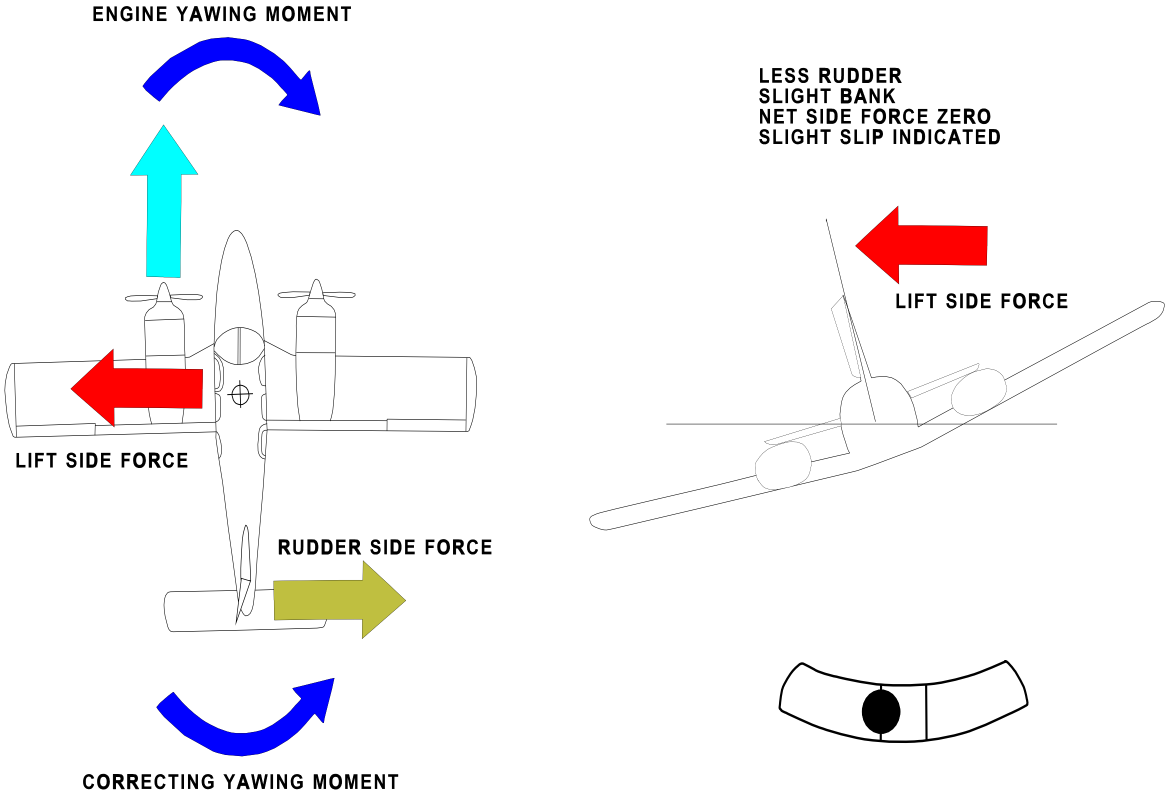
Each of these is now considered in turn.

13. **Wings Level and Sideslip Towards the Failed Engine** (Fig. 4). With the wings level the rudder is deflected to provide a yawing moment. There is now an unbalanced force acting across the relative airflow, and so to maintain equilibrium, the aircraft is sideslipped towards the failed engine, causing a side force to be created by the fuselage which, together with a sideways component of thrust, acts in opposition to that caused by the rudder. The artificial horizon shows wings level, and the ball of the slip indicator is in the centre, indicating no slip. (The compass heading is incorrect by the amount of the sideslip).

Of any method, this requires the most rudder deflection, because the rudder is opposing the natural directional stability.

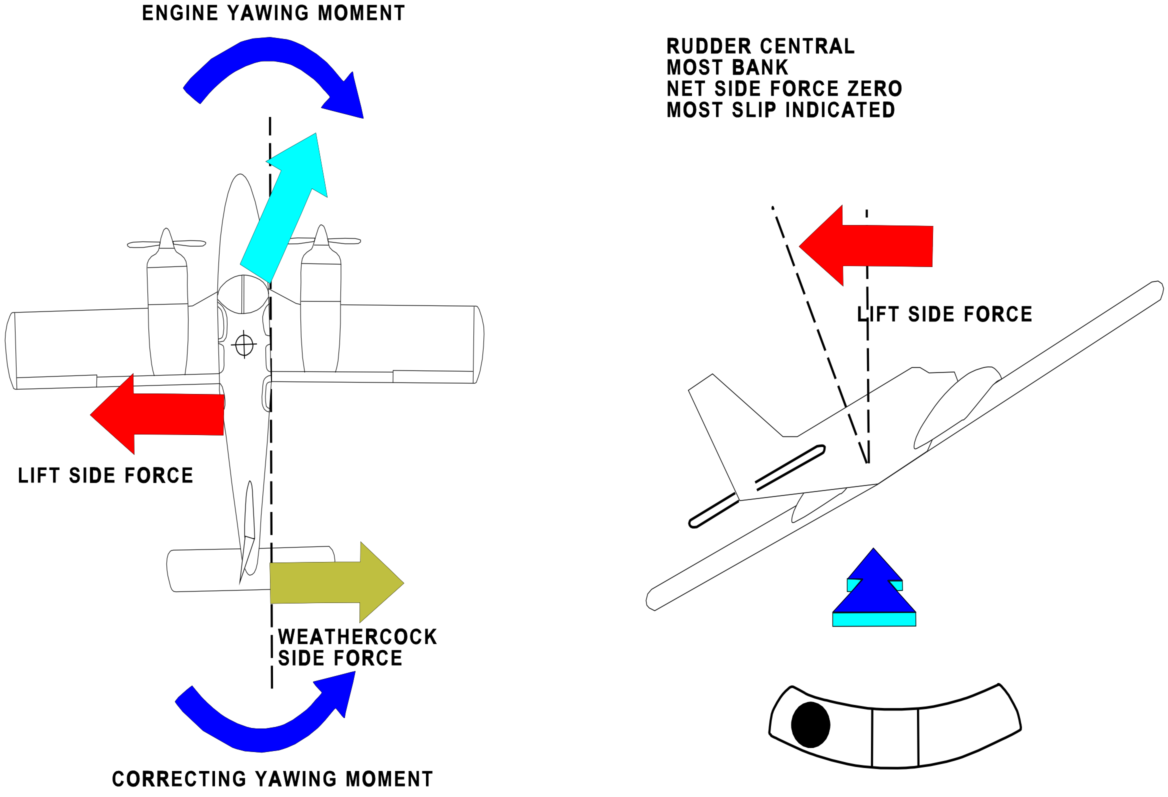


14. **Rudder and Bank Towards the Live Engine** (Fig. 5). Here the aircraft is kept pointing into the relative airflow and the side force to oppose that created by the rudder deflection is produced by a component of lift acting in the plane of the banked wings. Bank angles to do this are usually small (up to 5°). Instrument indications are imprecise since on most aircraft there are no true indications of sideslip. The ball of the slip indicator will be on one side towards the lower wing, merely indicating that a component of weight is acting in the plane of the wings. Compass heading is correct if there is no sideslip. This method is quite difficult to fly, particularly for a prolonged period, and especially if the aircraft is not fitted with an aileron trim control.



15. **Rudder Central, Bank and Sideslip Towards the Live Engine** (Fig 6.). This method may require up to 15° bank and a large angle of sideslip. It is possible that the fin may stall, and if the rudder is not clamped central it may aggravate control difficulties by locking over on a stop. The side component of thrust, the weathercock side force, including fin side force, are all acting in the same direction, and so the total force to oppose them is much larger. This means that a lot of bank has to be applied to obtain a larger component of lift along the plane of the wings. Instrument indications are of no use for precise flying. There is a large angle of bank and a very large amount of sideslip but there is nothing to tell the pilot how much these should be. The compass heading is incorrect.

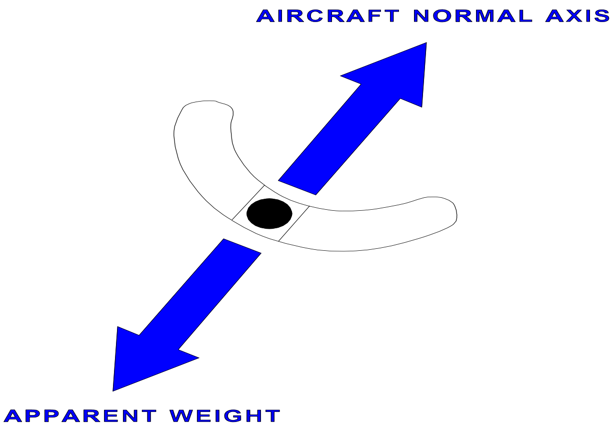
With the aircraft in an extreme yawed attitude, the total drag is high, and may be so high that level flight cannot be maintained. With the danger of loss of control, this method is not recommended.



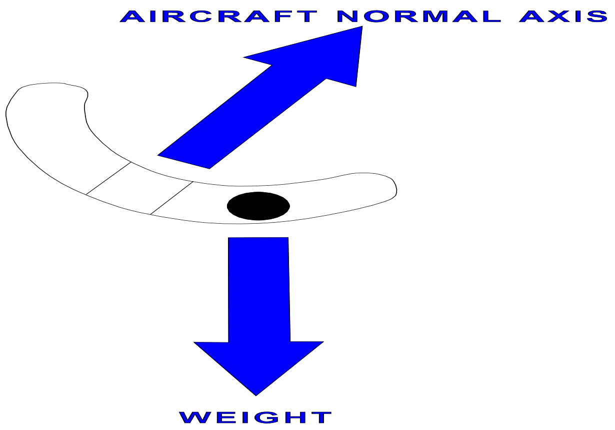
16. **Recommended Method.** The first method (para 13) - wings level - is recommended whenever it is possible. At higher speeds (for example, at or above 77 knots in the PA34) bank is not necessary. It has the advantage that there are correct artificial horizon and slip ball indications. Should rudder control be marginal at low speeds a small amount of bank towards the live engine (para 14) may be applied, and this will improve directional control (with a slight reduction of sideslip angle as a bonus).

A disadvantage of the recommended method is the sideslip towards the failed engine. It varies with IAS and with individual types of aircraft, but is usually less than 4° . The resulting slight increase in drag slightly reduces the range and general performance, but this is usually acceptable. The navigational problem caused by the sideslip is easily corrected as an extra drift.

17. **Slip Indications.** The slip indication in a normal balanced turn is illustrated in Fig. 7.




If now the aircraft is balanced but is not turning (Fig. 8) (vide paras 14 and 15) the slip indicator responds to the apparent weight as before. Many slip indicators reach their limit of travel at about 10° bank.



## SUMMARY

Factors affecting critical speed:

(a) The power or thrust of the live engine. The greater the power or thrust, the higher the critical speed.

(b) **The position of the Centre of Gravity.** An aft C. of G. gives a shorter rudder moment arm and therefore a higher critical speed.

(c) **Asymmetric Drag.** If the propeller of the failed engine is not feathered it will give more drag causing a higher critical speed.

(d) **Bank towards the live engine.** A small amount of bank towards the live engine will reduce the critical speed.

(e) **Drag.** Position of the undercarriage, flaps, cowl flaps.

(f) **Slipstream.** In some types of aircraft one engine may give a higher critical speed than the other due to slipstream effect.

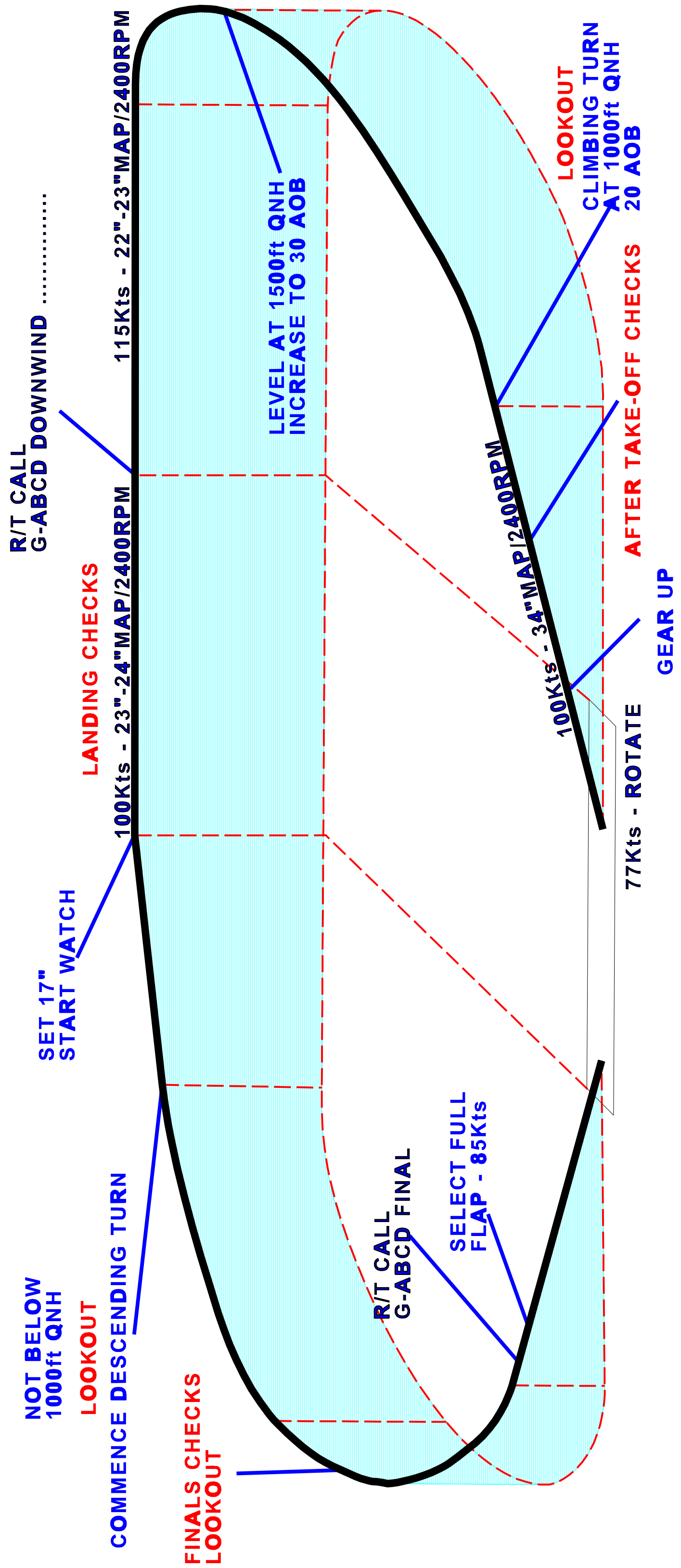
(g) **Asymmetric Blade Effect.** In some types of aircraft one engine may give a higher critical speed than the other due to an offset thrust line.

(h) **Turbulence.** The margin of control is less in turbulent conditions, giving a higher critical speed.

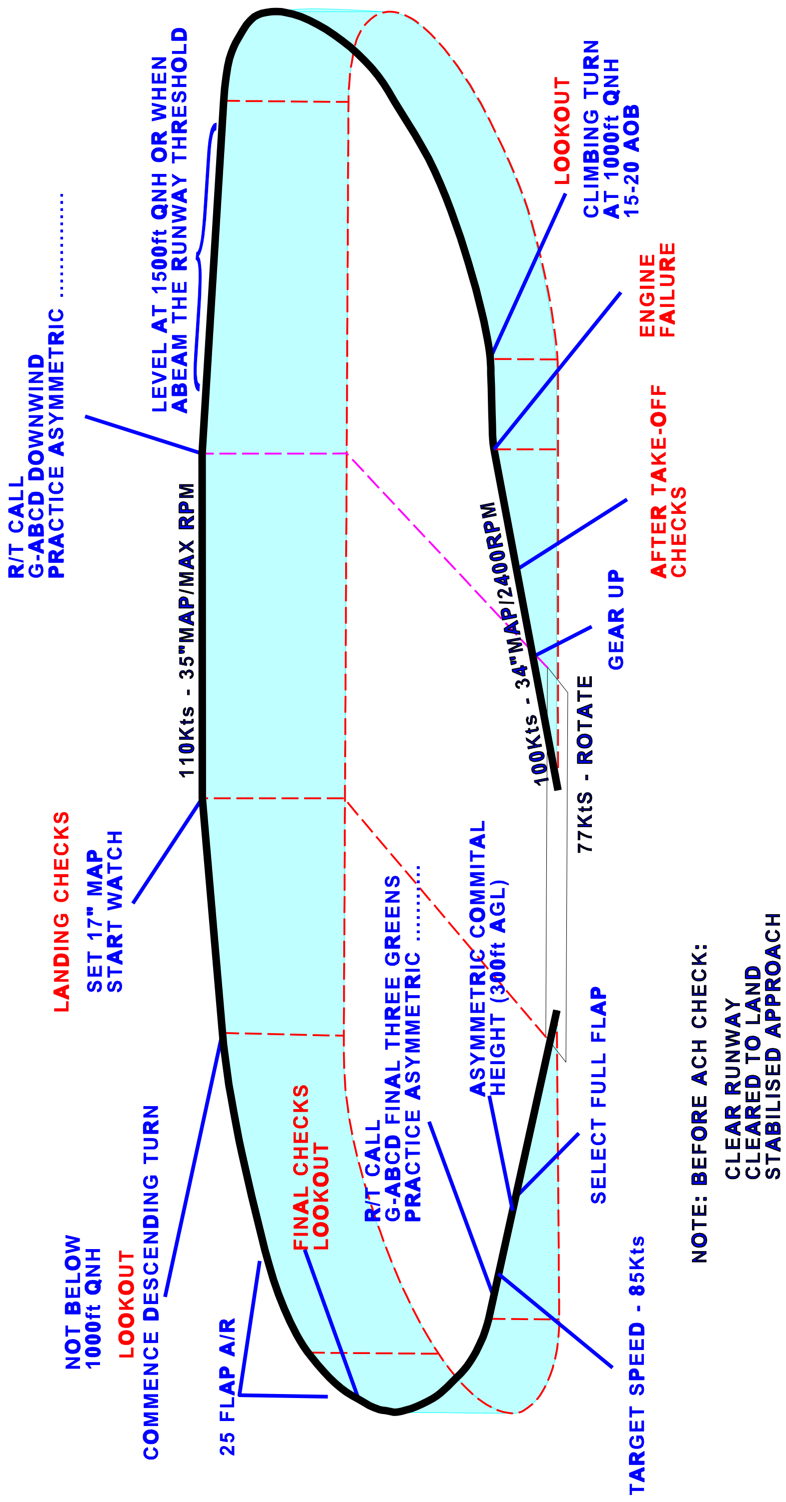
(i) **Altitude and Temperature.** The greater the altitude or temperature the lower is the critical speed.

(j) **Rudder Trim.** Use of rudder trim will slightly increase the critical speed.

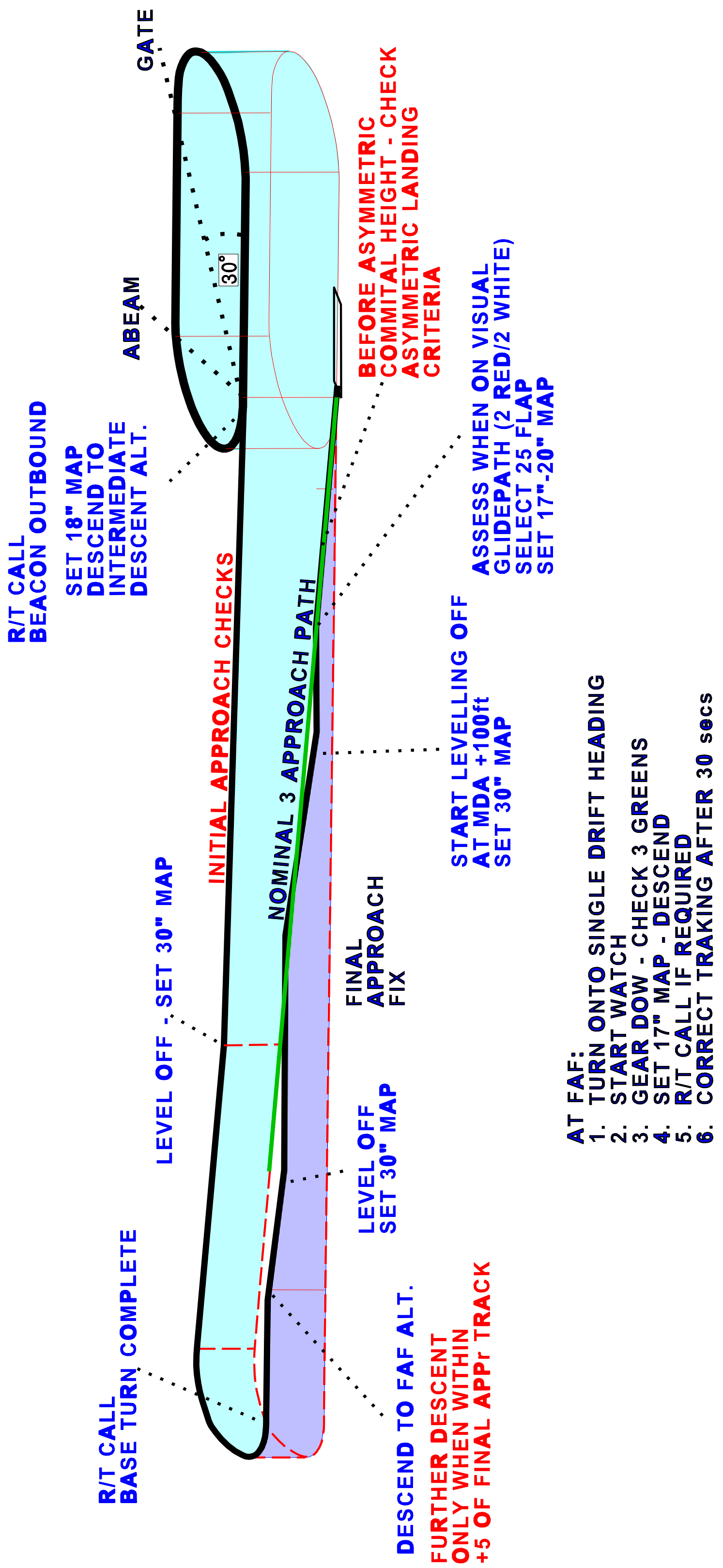
(k) **Strength and Skill of the Pilot.**




Appendix A **PA34 CIRCUIT**




Appendix B **PA34 SINGLE ENGINED CIRCUIT**




Appendix C **PA34 ILS/ADF PATTERN**