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MULTI-ENGINE FLIGHT MANUAL
FOR
PROFESSIONAL PILOTS

JOHN CHESTERFIELD AM MRAeS
PETER HAY

FOURTH EDITION

JULY 2007

MULTI-ENGINE FLIGHT MANUAL FOR PROFESSIONAL PILOTS

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Fourth Edition

JULY 2007

MULTI-ENGINE MANUAL FOR PROFESSIONAL PILOTS
INTRODUCTION

Fourth Edition – June 2007

Text, Illustrations and Diagrams – John Chesterfield

Nothing in this book supersedes any operational documents issued and amended by the Australian Civil Aviation Safety Authority or by Aircraft or Engine Manufacturers

National Library of Australia card number and ISBN:
0 646 14528 2

Published by Lindbush Pty Ltd (ACN 011 017 324) trading as Chesterfield Publications

Printed in Australia by Border Printing Services Pty Ltd
TWEED HEADS NSW

ACKNOWLEDGEMENTS

This book could not have been produced without the help of many people.

In particular, I wish to acknowledge the contributions of my two colleagues in this project - Peter Hay and Phil Becker - two fine aviators and instructors with a wealth of experience and knowledge, particularly in the operation of multi-engine aircraft and the training of multi-engine pilots. Regrettably, Phil died in February 1994. The continued production and popularity of this book serves as a fitting memorial to his contribution to aviation.

Thanks are also due to a number of other people, including my very good friends in CASA, who proof read the original manuscript and who made valuable suggestions on style and content.

Finally, for the **continued** patience and support of my wife Joan, who endured many lonely hours during the original production with wonderful good humour, provided essential administrative support and kept me supplied with sustenance while I was cloistered in my office researching, writing and drawing - THANK YOU.

SCOPE OF THE MANUAL

Multi-engine aircraft may be fitted with two, three or even four engines. However, the most common multi-engine aircraft used in General Aviation are the "twins" fitted with wing-mounted engines, and these are the subject of this Manual, specifically those with piston engines and with a maximum take-off weight less than 5,700 kgs.

Because of the general nature of this Manual, it **does not** replace the Pilot's Operating Handbook (POH) produced by the aircraft manufacturer. The POH is the authoritative document for each aircraft type, and should be the subject of repetitive study and be available for reference in flight.

While this book draws on material contained in these (and other) sources, it describes suggested procedures and techniques generally applicable to the operation of light twin-engine aircraft. It is based on the collective 63 years/20,000 hours flying experience of myself and my colleagues, including extensive experience in the training and testing of both military and civilian multi-engine pilots and instructors.

MULTI-ENGINE MANUAL FOR PROFESSIONAL PILOTS
INTRODUCTION

To help provide a sense of familiarity, the layout of this book follows the format of a typical POH.

In this fourth edition there are a number of editorial corrections, and an updated approach to the use of bank to maximise asymmetric climb performance. This update is based on a study by Melville R. Byington, Emeritus Professor of Aeronautical Science, Embry Riddle Aeronautical University, USA. The study by Professor Byington was published as an Appendix to a US AOPA Flight Safety Foundation pamphlet titled "Flying Light Twin-Engine Airplanes".

The Australian Syllabus of Training for Private Pilots does not cover the calculation of Points of No Return or Critical Points. However, I have become aware that many private multi-engine pilots use their planes for long overwater flights and I have therefore expanded Section 4 - Performance and Planning - to cover these subjects.

MULTI-ENGINE SAFETY

Flying (or more correctly, operating) a light twin-engine aircraft is not unusually difficult or demanding. Having two engines and the duplication of many systems means that twin-engine aircraft are inherently safer than singles, **provided** they are operated professionally.

Unfortunately, this built-in safety is also a factor in many light twin accidents, simply because many pilots become complacent about the possible effects of an engine failure on aircraft control and performance, and do not remain current with the the appropriate procedures. In some cases, multi-engine pilots not engaged in commercial operations **never** revise emergency procedures with a multi-engine instructor after their initial endorsement.

Light twin accident statistics show that while twins are involved in engine failure accidents less frequently than singles, those light-twin accidents which are caused by engine failure are usually more serious and often fatal. Many of the pilots involved were relatively experienced in total flight time and on the aircraft type, but either took the wrong action, or the right action much too slowly, because of lack of recent practice.

MULTI-ENGINE MANUAL FOR PROFESSIONAL PILOTS
INTRODUCTION

Depending on your experience, a 20-30 minute emergency procedures check flight with a qualified multi-engine instructor several times a year is probably the cheapest form of insurance you or your passengers will ever have!

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SECTION 1
SYSTEMS DESCRIPTIONS

MULTI-ENGINE MANUAL FOR PROFESSIONAL PILOTS
SECTION 1 – SYSTEMS DESCRIPTION

CONTENTS

AIRFRAME

GENERAL

The basic airframe design used in light twins is essentially the same as that of similarly sized singles from the same manufacturer. There is little difference in the internal cabin dimensions of singles and twins of the same seating capacity and manufacturer.

However, the additional mass of the second engine and the duplication of some systems means that a twin-engine aircraft will be heavier than a single of equivalent seating capacity. This extra weight requires larger structural components, such as the undercarriage, to cater for the higher weight.

The twin will have a higher cruising speed than an equivalent sized single, and this higher speed and higher weight of the twin increases the inertia of the aircraft. This will affect reaction to turbulence (gust response) and the rate of flight path change following a control input - a twin will generally feel more “solid” even though it is still quite responsive to control inputs.

PROPELLER SLIPSTREAM EFFECTS

The propeller slipstream over the wings has some important aerodynamic effects. The increase in air velocity over the wings behind the propellers increases the lift being generated by these parts of the wings. In addition, the engine nacelles also generate some lift. These effects may be noticeable when the throttles are closed for landing, and are significant in aircraft control in the event of an engine failure. This is covered fully in Section 3.

Figure 1 - 1 shows the lift distribution over the wings of a twin in normal flight.

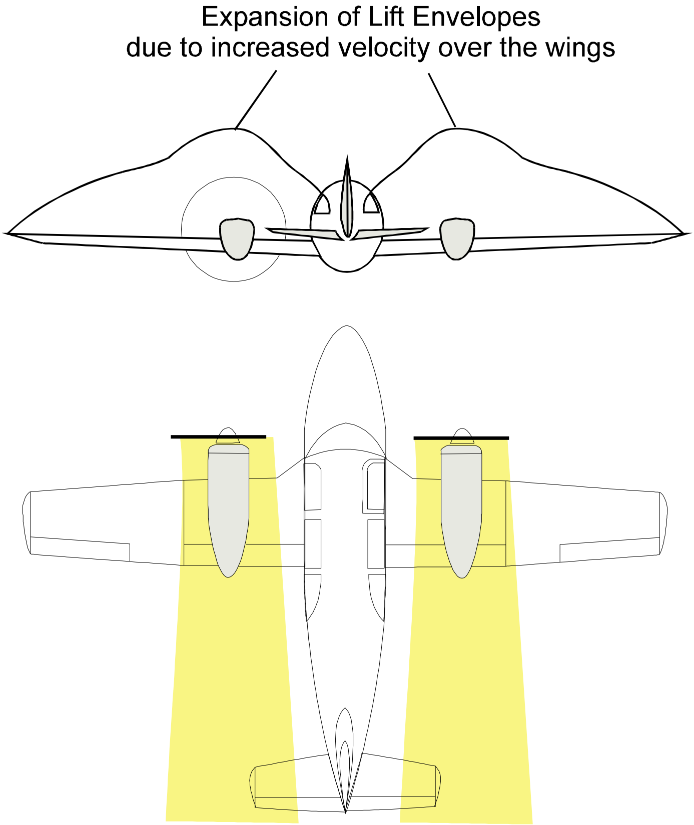

Figure 1 - 1. Slipstream Effect on Lift Envelope

NOSE BAGGAGE LOCKER

One difference in fuselage design is that the nose section of a twin will often be used as a baggage compartment. While providing additional stowage space, a nose baggage compartment adds another factor to the weight and balance calculations.

More importantly, the opened nose compartment access door(s) on some twins overlap the arc of the propeller tips.

The security of these doors is therefore an essential item in the pre-flight check list. On some of the affected aircraft, there have been instances of the doors opening in flight due to movement in the latch mechanisms caused by air loads or vibration. In these aircraft it is a mandatory requirement to lock the door latch with the key before flight - this requirement will be stated in the Pilot's Operating Handbook (POH)

NACELLE LOCKERS

In some larger twins, additional baggage lockers may be located in the aft section of the nacelle behind each engine. Again, these lockers add another factor to weight and balance calculations, and the security of their access doors is an additional pre-flight checklist item.

ADDITIONAL TRIM CONTROLS

Twins will normally have trim controls in all three axes - pitch, roll and yaw - although some of the lighter aircraft dispense with aileron trim. The rudder trim control assumes importance in the event of an engine failure. This is covered in Section 3 - Emergency Procedures.

Many twins may also have an electric elevator trim fitted in addition to the normal manual trim wheel. The electric trim switch is mounted on the pilot's control wheel. This trim switch may also incorporate an autopilot disconnect switch.

If an electric trim system is fitted, a trim interrupt switch may also be mounted on the pilot's control wheel adjacent to the trim switch. In the event of a runaway electric trim, the interrupt switch is held depressed until the electric trim circuit can be isolated, either by pulling a circuit breaker or by turning off the trim master switch.

Some manufacturers specify that an electric trim system must be turned off for take-off and landing.

ENGINES AND PROPELLERS

GENERAL

Apart from the fact that the engines are mounted on firewalls attached to the front of the wings, there is little difference between the engine installations of twins and those of singles with the same engine type.

COUNTER-ROTATING ENGINES

In some aircraft, the engines rotate in different directions to minimise control problems in the event of an engine failure (Refer to “Critical Engine” in Section 3). However, this counter-rotation can be a problem if you want to keep a spare engine or propeller on hand!

DUPLICATED COMPONENTS

Normally, engine driven components such as alternators and vacuum pumps are duplicated in twins. This duplication is a significant safety factor, particularly in IMC, but there is a minor penalty in having slightly more complex component control systems. However, most of the control systems which share the load between the duplicated components are automated in modern twins, requiring manual intervention by the pilot only in the event of abnormal system operation.

PROPELLERS

Propeller design is the most significant difference between twin and single engine aircraft.

Blade Angle Range

The propellers of a twin are designed so that the blades may be “feathered”, ie, rotated so that the blades are parallel to the relative airflow. This eliminates the drag of a windmilling propeller in the event of an engine failure. It also prevents continued rotation of a failed engine, preventing further damage if the failure was due to a mechanical fault.

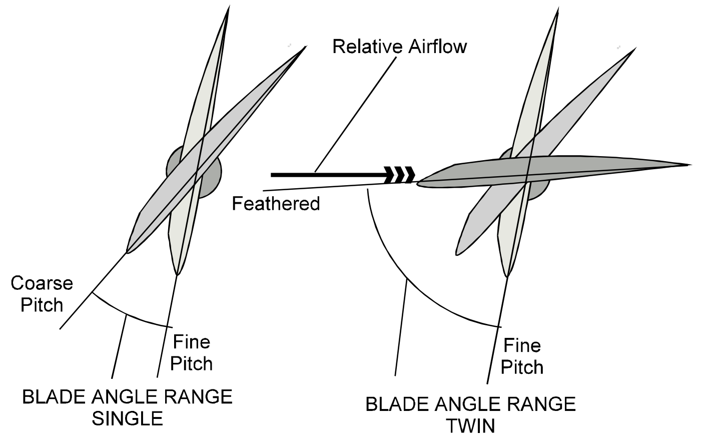

Figure 1 - 2 Comparison of Single and Twin Engine Propeller Blade Angle Ranges

Blade Angle Control

The blade angles of a twin-engine propeller are typically moved towards the fine pitch (high RPM) position by boosted engine oil pressure from the Constant Speed Unit (CSU), and towards the coarse pitch (low RPM/feathered position) by spring and gas pressure acting at the front of the propeller hub. Movement to the coarse pitch position may also be assisted by a centrifugal twisting force created by weights attached to the blade roots.

Centrifugal Latch

Given this design, the propeller blades would move to the feathered position as oil pressure is lost on engine shutdown. However, starting a piston engine with a feathered propeller would impose a heavy load on a starter motor.

To overcome this problem, propeller manufacturers incorporate a centrifugal latch in the propeller hub, which prevents the propeller blades moving to the feathered position when engine speed falls below about 800 - 1000 RPM. This ensures that the propeller cannot move beyond the normal coarse pitch position on shutdown.

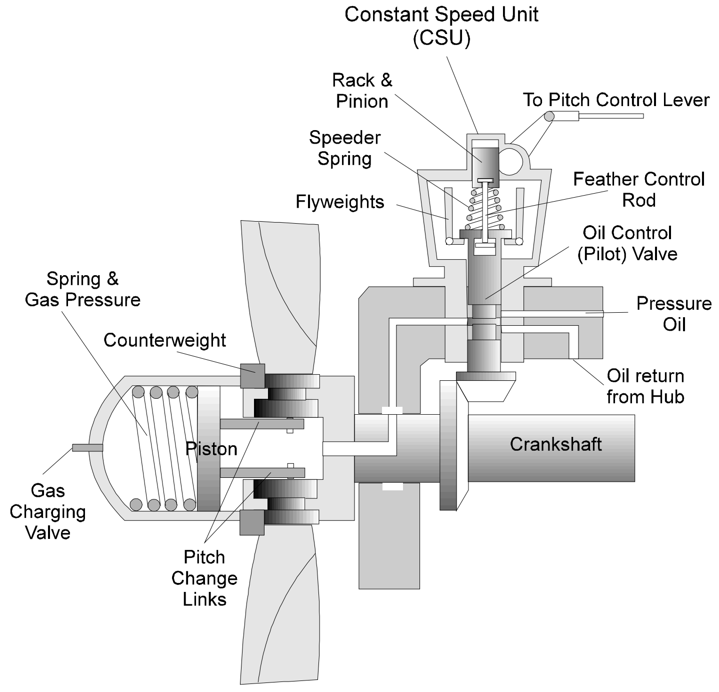

Figure 1 - 3. Typical Blade Angle Control System

However, a possible problem arises in the event of a mechanical engine failure in flight which causes a rapid reduction in RPM. If this occurs, and the propeller control lever is not moved to the “feather” position before the centrifugal latches engage, the propeller blades will not feather.

LOSS OF OIL PRESSURE IN FLIGHT

Because the blades are normally moved to the fine pitch position by oil pressure, a complete loss of engine oil pressure in flight may result in the blades moving to the feathered position (and probably the engine stalling) without any action by the pilot.

This will certainly get your attention and is a most effective oil pressure warning system! However, this same design feature may also prevent the expensive consequences of a seized engine and a potentially dangerous inability to feather the blades.

Because of the probable inability to feather a propeller if an engine seizes, precautionary engine shutdown and propeller feathering is a recommended procedure if oil pressure loss is detected in flight.

ENGINE/PROPELLER CONTROLS, AND ENGINE INSTRUMENTS

The engine and propeller controls and engine instruments in a twin are essentially the same as those in a single fitted with the same type of engine, except that the controls and instruments are duplicated. RPM indicators and manifold pressure gauges may be duplicated, or a single indicator may have two needles. These may be marked as L and R, or 1 and 2. By convention, No 1 is the left engine, No 2 the right.

Some larger twins may be fitted with an electrical RPM synchronizing system. These systems sense any variation in RPM between the engines, and position the CSU control on the "slave" engine to maintain synchronization of RPM.

Control of Feathering

The propeller controls are moved fully aft past the minimum RPM (coarse pitch) position to feather the propeller blades. Normally, there is a detent or a gate through which the levers must be deliberately moved to minimise the chance of an inadvertent feather selection.

When a propeller control lever is placed in the feather position, the oil control valve in the CSU is moved so that the oil in the propeller hub can flow back into the engine sump. The combined hub spring and gas pressure, possibly assisted by blade root counterweight centrifugal force, moves the blades rapidly into the feathered (streamlined) position.

Engine Restarting in Flight

An engine/propeller which has been shutdown/feathered in flight (during training or as a precaution) may be restarted using either the normal starter motor or, in aircraft so fitted, by an unfeathering accumulator.

To restart an engine with feathered propeller blades in an aircraft without unfeathering accumulators, the propeller pitch (RPM) control lever is moved forward of the feather position. As the engine is rotated by the starter motor, oil pressure builds up and flows to the propeller hub, and the propeller blades start to move from the feathered position.

As the blades move out of the feathered position, aerodynamic forces help to rotate the propeller and assist engine starting. The rapidly changing aerodynamic loads on the blades will usually cause significant, but momentary, engine vibration as the engine begins to run.

Unfeathering Accumulator

An unfeathering accumulator is a cylinder (normally mounted on the firewall) containing a floating piston. When the propeller blades are feathered, oil from the propeller hub flows into one end of the accumulator instead of into the engine sump, and the floating piston is forced along the cylinder, compressing the air on the other side. This stores (or “accumulates”) oil under high pressure.

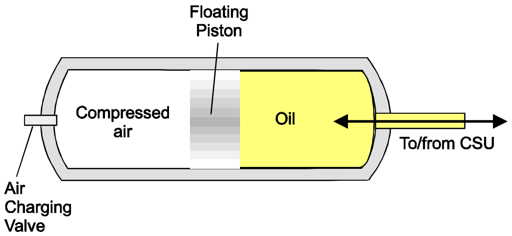

Figure 1 - 4. Typical Unfeathering Accumulator

If the propeller control lever is then moved forward out of the feather position, a valve in the CSU is opened. This allows the high pressure oil in the accumulator to flow back to the propeller hub, moving the blades from the feathered position. As the blades start to move, aerodynamic forces cause the propeller to rotate without the use of the starter motor.

Air starts using accumulators are generally much smoother, and save the stresses which are otherwise imposed on the starter motor and engine mounts as the propeller is unfeathered.

FUEL SYSTEMS

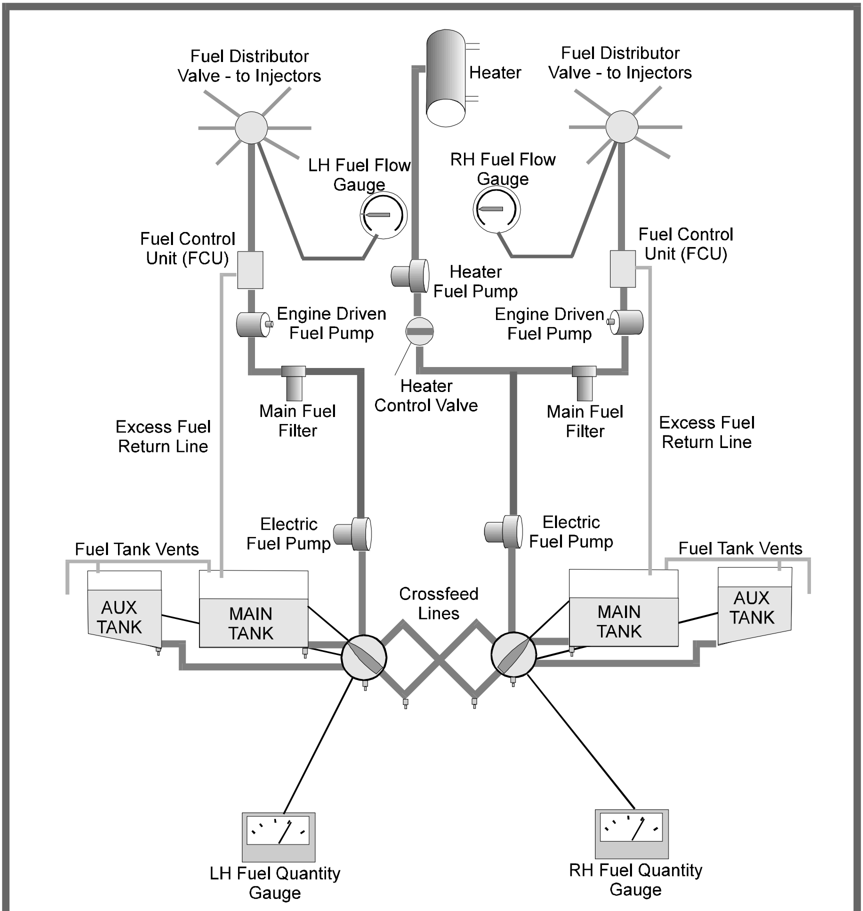

Figure 1 - 5. Typical Multi-Engine Fuel System

A typical twin-engine fuel system is shown in Figure 1 - 5

FUEL TANKS AND SELECTORS

During normal operations, each engine draws fuel from tanks in the same wing. However, in the event of an engine shutdown in flight, all the fuel on board should be available to the operating engine.

The fuel system design provides for fuel in the tank(s) in one wing to be "cross-fed" to the engine on the other wing. The fuel selector valves therefore have either a "crossfeed" position, or a separate crossfeed valve selector is located on the fuel panel.

All fuel selectors will have an "off" position to prevent fuel flowing to an inoperative engine, and particularly to an engine which has been subject to an in-flight fire.

In aircraft fitted with fuel-injected engines, there is normally a fuel return line from the engine Fuel Control Units (FCUs) to the main tanks. This line returns fuel in excess of engine requirements. In this type of system, it is important that the main tanks are used until the fuel level in the tanks has dropped sufficiently to accommodate the returned fuel before other tanks are selected. If this is not done, the excess fuel will be vented overboard if the main tanks are full.

MAIN AND AUXILIARY TANKS

Fuel may be contained in either one, or in a number of tanks, in each wing. If more than one tank is installed, they may be either interconnected, eg, Piper Seneca, or be capable of separate selection, eg, Cessna 310.

Where tanks have separate selection, they are normally referred to as main and auxiliary, with the main tanks normally having the larger capacity. However, the auxiliary tanks in the Beech Travelair, for example, have a larger capacity than the main tanks.

MINIMUM FUEL TANK QUANTITY

Because of the location and design of some wing mounted tanks, and the possible effects of slip or skid on fuel flow, some aircraft have restrictions imposed on the tanks which may be selected for take-off and landing. There may also be restrictions imposed on the minimum fuel quantity in these tanks for take-off.

ADDITIONAL FUEL TANKS

In addition to main and possibly auxiliary tanks within the wing structure, some manufacturers offer additional fuel capacity in optional tank installations, typically in the fairings behind the engines.

Fuel from these tanks is usually transferred by pilot activated electric pumps to the main tanks after sufficient fuel has been used from the main tanks.

These optional tanks are often not fitted with fuel gauges, and indicator lights are used to show when the transfer of fuel has been completed.

FUEL QUANTITY GAUGES

There may not be separate fuel quantity gauges for each tank. The same gauge(s) may be used for separate tanks, with the quantity transmitter in each tank connected to the common fuel quantity gauge by tank selection. In some aircraft, the left/right gauges are connected to each tank quantity transmitter by a separate "main/aux" switch selection.

The fuel systems of light twins may be either relatively simple or somewhat complex, particularly if extra capacity options are fitted. The design and operation of fuel systems of individual aircraft, even of the same type, may differ markedly from those with which a pilot is familiar.

Therefore, the operation of the systems of individual aircraft (particularly use of the crossfeed system) as shown in the POH must be studied carefully and fully understood before flight.

WARNING

MANY ACCIDENTS HAVE OCCURRED BECAUSE OF INCORRECT FUEL TANK SELECTION OR QUANTITY MISINTERPRETATION, AS A RESULT OF PILOT UNFAMILIARITY WITH A PARTICULAR FUEL SYSTEM DESIGN.

AUXILIARY FUEL PUMPS

Most multi-engine aircraft are fitted with auxiliary fuel pumps (sometimes called "boost" pumps). These pumps "back up" the engine driven fuel pumps to ensure continued operation in the event of an engine driven pump failure.

The pumps may have a simple “on/off” switch or be capable of operating at two speeds. In this case, the pump control switch will be labeled “low/off/high”.

In the case of aircraft fitted with fuel injected engines, the aux pumps may also be used for engine start priming.

Use of the pumps after engine start and before shutdown varies between aircraft. Some system designs require that the pumps be switched “on” or to “low” for take-off and landing, and to remedy fuel pressure fluctuations during flight caused by fuel vaporisation.

The “high” setting in two-speed pumps is normally only selected if the engine driven pumps fails, indicated by loss of fuel pressure and probably momentary engine failure. In some installations, the two-speed pumps will switch automatically from “low” to “high” speed if the engine-driven pump outlet pressure drops below a preset value, to provide sufficient fuel pressure for continued high power engine operation.

If the “high” setting is selected when the engine-driven pump is operating normally, the engine may be flooded and experience a “rich cut” until the aux pump is selected to “off” or to “low”

In some aircraft, such as late-model Piper Navajos and in the Piper Chieftain, a second low pressure pump is installed in each side of the fuel system. These pumps run whenever the battery switch is on. Their main purpose is to pressurise the fuel lines and prevent vaporisation.

If the mixture controls are opened before engine start while these secondary pumps are running, the intake manifolds will be flooded with fuel, and if the starter is engaged a hydraulic lock may occur in one or more cylinders. This can cause damage to connecting rods. Therefore, if the mixture control has been opened inadvertently with these pumps running, the manufacturers normally recommend a wait of up to five minutes for the excess fuel to drain from the manifolds and cylinders.

Some operators pull the circuit breakers for these secondary pumps as part of the after-landing checks, and reset them just before engine start.

Where a manufacturer recommends that aux fuel pumps are to be selected on for take-off and landing, don't select them off until about 1,000 feet in the initial climb.

Many pilots have the bad habit of switching these pumps off at about 2-300 feet after take-off. If an engine-fuel pump has failed during the take-off, and the aux pump is the only thing keeping the engine running, I would rather have an engine failure at 1,000 than 200 feet! I also recommend switching these “take-off and landing” pumps on at any time when operating below 1,000 feet AGL

The bottom line with regard to aux fuel pump management is to read the POH carefully, understand the system design and use the pumps as the manufacturer intended.

ELECTRICAL SYSTEMS

The electrical power sources in most light twins are duplicated, with each power source sharing the load under normal operations.

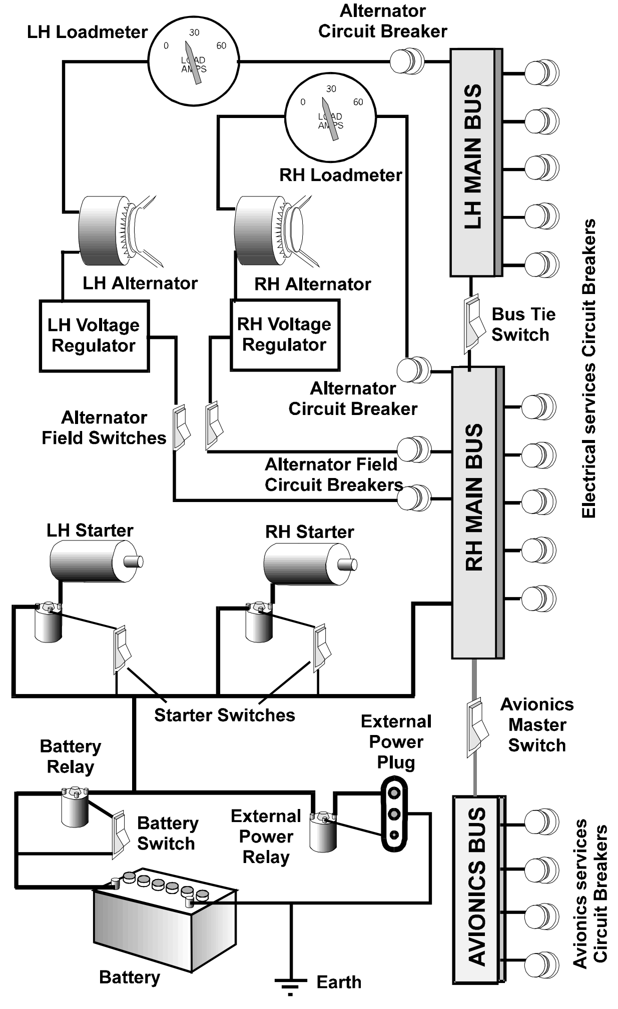

Figure 1 - 6. Typical Multi-engine Electrical System

Although some of the older twins are still fitted with generators, the remainder of this Section will refer only to alternators. Figure 1 - 6 is a schematic diagram of a typical light twin electrical system.

ALTERNATOR CONTROL SYSTEMS

In many twins, each alternator will supply power to a separate “bus” or main circuit.

The left and right “buses” are normally interconnected, but in some installations they may be disconnected from each other by pilot switch selection, to isolate faults in one side from the other. In these installations, electrical services are spread between the “buses”.

Services essential to continued flight may also be connected to a separate battery “bus” as a protection against a double alternator failure.

Alternator Field Switches

There is normally no reason to turn alternator field switches off at engine shutdown, and on again after engine start. Unless specifically stated otherwise in the POH, these switches may be left on at all times. However, the POH may specify that they should be turned off during a start using external power.

There have been a number of accidents where pilots have forgotten to turn on the alternator field switches before flight, and then suffered the inevitable battery failure. Alternators must be “excited” by battery voltage to begin generation of power - that is why all flight manuals contain the warning “Do not switch off alternators in flight except in an emergency”!

Voltage Regulators

Some twins have a separate voltage regulator connected to each alternator, while others have one regulator controlling both alternators. In this latter case, a stand-by (“back-up”) regulator is fitted, and either one may be selected by a pilot-activated switch, which may be labeled “main/stand-by” or “No 1/No 2”.

To ensure that both are regularly checked for serviceability, a recommended procedure is to change the selection before each flight during the pre-start checks.

If the aircraft is flown on a daily basis, use the main (No 1) regulator on odd dates and the stand-by (No 2) regulator on even dates.

Ammeter/Loadmeters and Voltmeters

Twins may either have separate ammeters/loadmeters for each alternator, or have a common instrument (sometimes a combined volt/ammeter) with a rotary switch to select the desired display.

Irrespective of the display type, if the alternator control systems are functioning properly, the ammeter/loadmeter readings for each alternator will be approximately equal.

If there is a significant difference indicated between the left and right alternator outputs (particularly if no load/output is indicated on one), this is usually an indication of either:

a. an impending or actual alternator/voltage regulator failure, or

b. the alternator output voltages being controlled by separate regulators are significantly different, ie, not “parallel”.

In either case, maintenance is required, particularly where the alternators are gear-driven, as in some Continental engines. Alternator failure in these cases can lead to serious (and expensive) internal engine damage.

Installing a Voltmeter

Because of the system design, some ammeters may not clearly indicate that alternators are providing power to the aircraft electrical system. Therefore, the fitting of an inexpensive separate voltmeter as a modification is strongly recommended. Although a simple procedure, this modification must be done by a licensed engineer.

If indicated system voltage is above that of the nominal battery voltage, then power is being supplied to the electrical system from the alternator(s). Typically, if a 12 volt battery is fitted, the voltmeter will read about 14 volts if the alternators are working. In a 24 volt system, the voltmeter should read about 28 volts with the alternators “on line”.

A voltmeter can also warn of over-voltage which may damage avionics components. It may also be a useful and money saving “troubleshooting” tool, because an engineer may be able to quickly isolate a system fault if given voltage readings associated with an observed problem.

ALTERNATOR FAILURE

In-flight failure of an alternator or voltage regulator normally requires some action by the pilot. The required action, including the method for an attempted alternator “reset”, is detailed in the POH. Instrument Power Systems

INSTRUMENT SYSTEMS

POWER SOURCES

Although some larger aircraft may have gyro instruments which are electrically powered, the main flight instruments are normally powered by air pressure generated by pumps fitted to each engine. These pumps are connected to a common manifold.

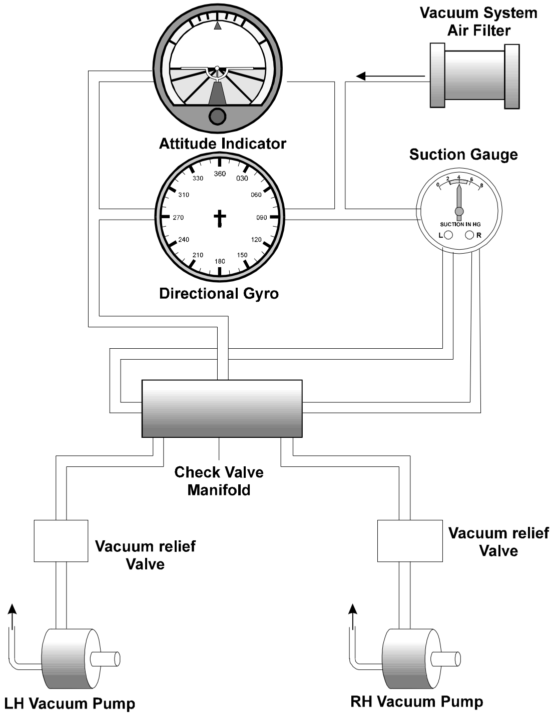

Figure 1 - 7 Typical Multi-engine Vacuum System

This manifold contains a valve mechanism which will automatically isolate a failed pump, with the remaining pump having sufficient capacity to maintain system serviceability.

PRESSURE AND VACUUM PUMPS

On most light twins, the engines driven pumps suck air through the manifold from the gyro instrument (AH & DI) cases, causing outside air to be drawn through filters into the instrument cases to spin the gyros.

In larger twins, particularly those which are fitted with (or for) pneumatic de-icing boots, the engine driven pumps provide a positive pressure to the instrument cases to spin the gyros.

VACUUM/PRESSURE INDICATORS

In either case, the pressure in the manifold (either positive or negative) is indicated on a gauge, which also normally incorporates two red “doll’s eye” indicators, one for each pump. When a pump is working correctly, it’s “doll’s eye” will not be visible. Conversely, a pump failure is indicated by a “doll’s eye” becoming visible.

The indicators are checked on engine start and shutdown. If the left engine is started first, it is also shut down first to check that the left “doll's eye” is displayed with only the right engine running.

If neither “doll's eye” indicator is visible with only one engine running, an isolating check valve has probably failed, and servicing is needed to ensure proper system operation in the event of a vacuum/pressure pump failure.

AVIONICS

Most light twins are equipped and maintained for IFR operations, and are therefore fitted with a more comprehensive set of avionics than many singles.

AVIONICS MASTER SWITCHES

Power to the avionics sets may be centrally controlled by an avionics “master” switch or, as in the case of the Beech Duchess, two switches - one for each avionics “bus”. Where avionics master switches are provided, the individual power switch on each avionics set is normally left on.

In many aircraft, a “stand-by” avionics power switch is installed to ensure continued operation in the event of an internal failure of the avionics master switch. In other aircraft, eg, Beech Barons and Bonanzas, pulling the avionics master switch circuit breaker will isolate the master switch, and provide continued avionics power.

AVIONICS SYSTEM OPERATING INFORMATION

Detailed information on the operation of avionics systems and components is usually contained in the Systems Description and/or Supplements Sections of the POH. If no information is available, the nearest Avionics Maintenance shop should be able to provide detailed instructions covering all operating procedures.

Audio Selector Panel

In addition to the communications (Comm) and navigation aid (Nav) sets, an audio control panel is also installed. This enables the pilot to selectively monitor the audio output from each comm and nav set, either through a cabin speaker or headset(s) - (or in some cases both).

The audio panel also normally provides for a selection between comm set transmitters. On those panels which have an audio switch marked “auto”, this automatically connects the audio output of the comm set selected by the transmitter switch to the speaker or headset(s), without the need to separately select the appropriate audio selector switch.

For example, if the aircraft is fitted with two VHF comm sets, the “auto” switch is selected to “phones”, and the transmit selector is on VHF #1, the output from VHF #1 will be heard in the headset even though the VHF #1 audio switch is off (provided the volume is turned up!).

There may be significant differences in audio panel operation between aircraft. A comprehensive briefing by an experienced pilot or instructor on switch selections in an unfamiliar aircraft will probably save valuable time (and money), and also may save considerable embarrassment.

As an alternative, get the avionics manufacturers' instruction book(s), connect an external power source and spend some time in the cockpit becoming fully familiar with the avionics equipment operating procedures.

ENVIRONMENTAL SYSTEMS

AIR CONDITIONERS

The cabin environment control systems in many twins are essentially the same as for a single from the same manufacturer. Some of the bigger twins are fitted with air conditioners, with the compressor belt-driven by one of the engines. These air conditioning systems and their controls are virtually identical to those fitted to cars.

Use of Air Conditioners During Take-off and Landing

Although air conditioners may be operated either on the ground or in the air, they should normally be switched off for take-off and landing, as operation of the compressor will reduce the power output of the driving engine. This could be critical in high density altitude/short field situations, or in the event of a baulked approach. The POH will specify if this is a requirement.

CABIN HEATING SYSTEMS

Some twins still use a muff around the exhaust pipe(s) as a source for cabin heat. However, the more common heat source is a fuel-fired combustion heater. These heaters, which draw fuel from the engine fuel system, are located in the main cabin air intake duct, but have a separate air intake and exhaust system. The metal skin of the combustion chamber passes heat by conduction to cabin air flowing past it.

The heaters are fitted with hour-meters and must be inspected at regular intervals, and they are protected by a number of safety devices.

In most installations, the heater will not function unless the cabin air intake valve is at least half open. When the heater is switched on, a fan in the main air inlet duct (which can be separately selected to ventilate the cabin) is automatically energised to ensure a positive airflow over the skin of the heater combustion chamber.

In some installations, this fan is switched off automatically when the aircraft becomes airborne, and positive airflow is then provided by ram air.

The heater system incorporates a thermostat which is set by the pilot to maintain a desired cabin temperature, and the heater cycles on and off automatically to maintain the selected temperature.

A typical heater will use about 2/3 of a US gallon per hour.

Cabin Overheat Protection

If the cabin air intake duct becomes too hot, an overheat warning light will illuminate and an overheat thermostat switch will automatically shutdown the heater. If this occurs, the switch can only be reset on the ground.

This should be done by an Engineer after the cause of the overheat has been determined and fixed.

Heater Duct Cooling after Landing

If a heater has been on throughout the flight and landing, the intake duct fan should be switched on for a few minutes after the heater is switched off after landing, to cool the heater combustion chamber and duct.

PRESSURIZATION

GENERAL

Pressurization of the aircraft cabin is a design feature of some larger turbo-charged twins which enables them to cruise above 10,000 feet without the need for crew and passengers to use oxygen continuously.

REQUIREMENT FOR OXYGEN

However, oxygen must be available to the crew and to a percentage of the passengers for all flights conducted above 10,000 feet. The duration of the oxygen supply must be sufficient to enable a descent, without exceeding aircraft speed limitations, to at least 14,000 feet in the event of a depressurization. The oxygen duration is dependent on whether the cruising altitude is above or below 25,000 feet - CAO 20.4 Sub-Sections 7 and 8 specifies the requirements.

POSSIBILITY OF ICING

Although one advantage of pressurization is the ability to fly above the weather, flight above 10,000 feet in IMC carries with it the possibility of airframe and engine icing.

Unless the aircraft is equipped with approved de-icing or anti-icing equipment, the pilot of a pressurized aircraft must consider the possibility of icing at the flight planning stage, eg, cloud type and amount, height of the freezing level, and be prepared to descend below the freezing level if necessary.

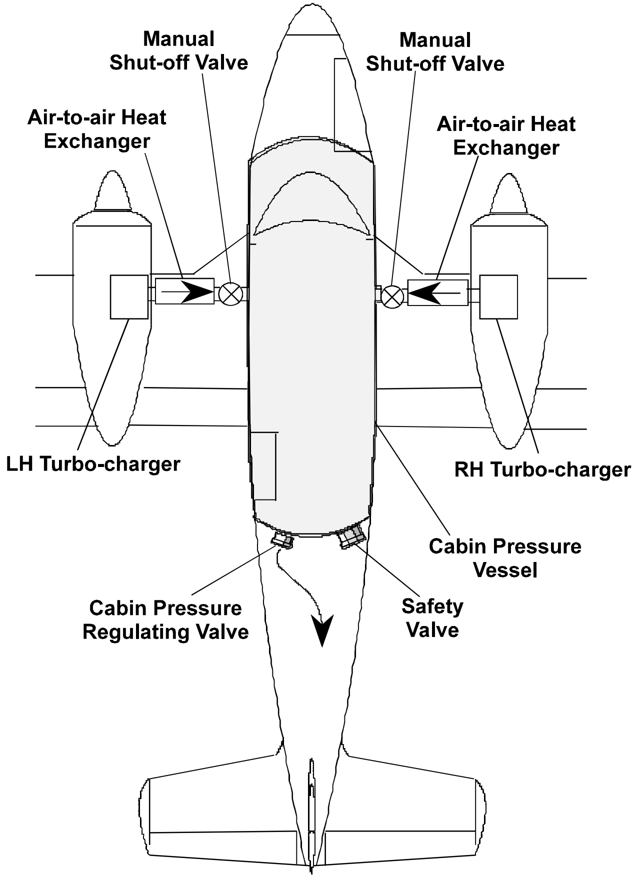

Figure 1 - 8. Typical Multi-engine Pressurization System

PRESSURIZATION DESIGN FEATURES

Airframe Structure

The cabin of a pressurized aircraft is essentially a sealed capsule, with the structure (including all windows and entrance doors, etc.) designed to safely contain the maximum pressure which may be encountered in service. This is normally in the range of 4 to 6 pounds per square inch.

Air under pressure is provided from the engines, and the cabin altitude (pressure) is controlled by an exhaust valve, normally located in the rear cabin bulkhead. The pressure in the cabin is controlled by regulating the amount of air being exhausted from the cabin.

Cabin Air Supply and Temperature Control

The air used to supply cabin pressure is normally provided by bleeding some air from the turbocharger compressors. An alternative supply source may be the engine-driven air pressure pumps used to provide air for gyro instruments (and for de-icing equipment if fitted).

The pilot is provided with mechanical controls to close off the cabin air supply. The quantity of air from either engine will normally be sufficient to maintain a selected cabin altitude.

Cabin Inlet Air Temperature Control

Compressed air from the turbochargers is at a relatively high temperature, and many aircraft have air-to-air coolers (radiators) fitted in the leading edges of the wings between the engines and the cabin. The pilot may control the volume of cooling air flowing through these radiators by adjusting shutters in front of the radiators, providing primary control of cabin inlet air temperature.

Additional Cabin Temperature Control.

In addition to the control of cabin air inlet temperature, many pressurized twins are also fitted with air conditioners, enabling the pilot to select a temperature which will provide a comfortable cabin environment irrespective of the outside air temperature.

Cabin Pressure Regulating Valve

The cabin pressure regulating valve, which is normally located in the aft cabin bulkhead, responds to the cabin altitude and rate of change set by the pilot. This valve exhausts air from the cabin as needed to maintain the desired cabin altitude and rate of cabin altitude change.

Safety Valve

In addition to the pressure regulating valve, a safety valve is also fitted to ensure that the maximum safe value of cabin pressure cannot be exceeded. This valve is also normally controlled by the pressurization on/off switch.

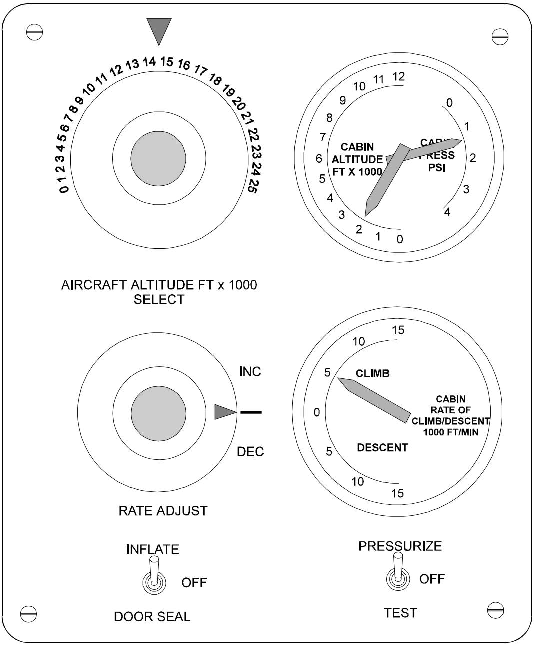

Figure 1 - 9. Typical Pressurisation Control Panel

CONTROL OF CABIN ALTITUDE (CABIN PRESSURE)

The pilot is provided with a control panel which enables the selection of:

a. pressurization on or off;

b. cabin altitude; and

c. rate of change of cabin altitude during climb and descent.

PRESSURIZATION CONTROL PROCEDURES

Pressurization Control procedures are covered in Section 2 - Normal Operating Procedures

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SECTION 2

NORMAL OPERATING PROCEDURES

MULTI-ENGINE FLIGHT MANUAL FOR PROFESSIONAL PILOTS

SECTION 2 – NORMAL PROCEDURES

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MULTI-ENGINE FLIGHT MANUAL FOR PROFESSIONAL PILOTS

SECTION 2 – NORMAL PROCEDURES

USING A CHECKLIST

Normal operating procedures and techniques for a light twin are essentially the same as for a modern single-engine aircraft. However, given:

a. the duplication of many of the systems, and

b. the probable increase in the complexity and number of cockpit controls,

the use of a written, rather than a memorised, checklist is strongly recommended. This will ensure that no vital item is overlooked (particularly before take-off) and will help to streamline and simplify cockpit procedures. A written checklist should be used as a “check”, not a “do”, list. By that I mean that checks can be performed from memory if preferred, but the check list should then be consulted to make sure that all items have been covered.

MEMORIZED CHECKLISTS

However, there are some checklist sections which must be memorised and performed correctly without the need to refer to the written checklist. These are the taxi, after take-off and before landing checks, which are normally completed when your eyes should be outside the cockpit, not on a checklist.

PHASE ONE CHECKLIST ITEMS

The immediate actions required in the event of critical emergencies must also be memorised. These are called “Phase One” or “Bold Face” items - they are usually shown in a POH checklist in bold type. “Phase Two” or “Clean-up” checks, or those related to abnormal, rather than emergency, procedures should always be completed by reference to the POH checklist, in the Emergencies (Red Tab) Section.

CHECKLIST CONSTRUCTION

The POH will usually contain a suggested checklist covering all phases of flight. If it doesn’t or if you prefer a custom-made checklist, you can construct one which should start with “documentation complete, seats and seat belts adjusted and secure, park brake set”.

Sit in the aircraft and look at all instruments, controls and switches in turn from left to right and down the centre (don't forget any overhead panel(s)).

As you look at each item, ask yourself the question "if I didn't check this item and it was incorrectly set for start or flight, would it be potentially:

a. dangerous,

b. damaging, or

c. very embarrassing".

If the answer to the question is "yes", that item should be added to your custom-made checklist.

The checklist in the POH is the CASA-accepted check system. If you decide to construct a "custom" checklist, you should submit it to the local CASA Field Office for approval under CAR 232 (2) for warranty, liability and insurance purposes.

VERIFYING CHECKLIST COMPLETION

On completion of each section of a checklist, say to yourself "......... checks complete", just like the airline pilots do to confirm that the relevant section of the checklist has been completed; this is particularly important if a checklist section has been interrupted for some reason, eg, radio response requirements.

PRE-FLIGHT INSPECTION

Because of the increased complexity of a twin, the pre-flight inspection will take more time, and this should be allowed for in planning. A rushed pre-flight is a recipe for disaster.

FUEL DRAINS

The probable multiplicity of fuel tanks can mean that there will be numerous fuel drain points. Some drains, eg, cross feed drains and fuel selector drains, may be hidden from sight under the fuselage centre-section or wing root area, possibly under a hinged panel cover.

To properly drain the fuel lines from a tank to a fuel selector drain, the fuel selector may first need to be set to that particular tank. This check on tank-to-selector valve plumbing must always be done if any contamination is detected in the tank drain!

PRE-FLIGHT CHECK TECHNIQUE

To start the pre-flight, first check the cockpit. The gear selector should be checked "down", then switch the battery master switch on, check the battery voltage (if a voltmeter is fitted), check the fuel quantity shown on the gauges for comparison with the visual check in the tanks, select the flaps down, then turn the battery master switch off and remove the control locks. Cowl flaps, if fitted, should also be opened to facilitate inspection of the rear of the engine nacelle.

The external inspection should then be completed methodically in one pass around the aircraft, starting at the pilot's entrance door and proceeding completely around the aircraft back to the starting point. Remember to double check, and if required key-lock, baggage compartment doors.

If some activity, eg, refueling or baggage stowage occurs after you have completed the pre-flight, complete that part of the pre-flight again.

PRE-START CHECKS

PRE-START CHECK TECHNIQUE

After you have adjusted (and locked) your seat, fastened your seat belt and set the park brake, the pre-start checks should be done methodically, left to right, using the checklist. If some piece of equipment is not working and needs maintenance attention, it is better to find out before-start than at the holding point, or even worse, after take-off, particularly in the case of IFR flight!

If the aircraft is fitted with more than one fuel tank per engine, start and taxi on the tank(s) which will **not** be used for take-off.

PRE-START CHECKS AT TRANSIT STOPS

Some items may only require checking on the first flight each day, and may be passed over at transit stops. Mark these items on the checklist with an asterisk, or some other symbol.

COCKPIT ORGANIZATION

The pre-start check should routinely include cockpit organization, ie, stowage of all documents, etc for easy access in flight. This includes the POH, which must be accessible in the event of an emergency or abnormal system operation.

ENGINE STARTING

FUEL PRIMING

Some carburetor-equipped twins are fitted with two manual priming pumps, one for each engine. Because of the length of the priming lines, more priming strokes may be needed than in a single; about two strokes are needed just to fill the lines before fuel begins to flow into the engine intake ports.

Make each stroke slow and deliberate — the inlet valve in the priming pump is small and the pump takes about one second to fill when the plunger is pulled out.

Alternatively, some carburetor equipped twins have an electric priming switch incorporated in the combined magneto-starter switches. The electric priming pump is activated by pushing the switch in, normally while the starter is engaged.

Twins with fuel-injected engines are primed by either:

a. operating the booster pumps for a second or two with the mixture and throttle levers forward just before starting, or

b. operating a separate priming switch either just before or during operation of the starter.

Whatever priming system is fitted, follow the priming procedure recommended in the POH.

MAGNETO SWITCH TYPES

Unlike most singles which have a combined key-operated magneto/starter switch, many (most) twins have individual magneto switches and a separate starter switch. If an engine shows no sign of starting during the first attempt, check that the magneto switches are on!

ORDER OF ENGINE STARTING

The left engine is normally started first as it is easiest to clear visually from the pilot's seat. The sound of this engine starting should alert anyone who may be standing in a “blind spot” on the right hand side.

However, if there is any doubt about the battery capacity and it is not mounted near the aircraft centre-line, first start the engine which is closest to the battery. The shortest cable run will give the lowest voltage drop during starter use.

STARTER SWITCH OPERATION

Before engaging a starter, be sure you have your finger on the correct switch. Engaging the starter on an engine which is already running can ruin your whole day, not to mention the Bendix drive and/or the starter mounting flange!

Starter Duty Cycle

Once the starter is engaged, keep it turning for a reasonable period of time and give the engine a chance to begin running. A typical starter normally has a duty cycle of 30 seconds on, 2 minutes off, 30 seconds on and then 30 minutes off. The quickest way to flatten a battery and heat-damage a starter is to engage it frequently for short cranking periods - the greatest current draw and heat generation is during each separate application of electrical power.

AFTER START CHECKS

After the first engine is started, check oil pressure, instrument pressure/“doll’s eye” and alternator output before starting the second engine and repeating the process.

There is normally no hydraulic pressure gauge in aircraft fitted with engine-driven hydraulic pumps. However, in the Piper Navajo and Chieftain, for example, the undercarriage lever is selected down and will spring back to neutral if the hydraulic pump is producing pressure.

STARTING WITH AN EXTERNAL POWER SOURCE

USE OF POH

Because external power starts are not normally an everyday procedure, we recommend that you always consult the POH before an external power start. Some aircraft require that the battery master switch be on, others don’t. Incorrect switch selection could damage the aircraft electrical system. Before beginning the starting procedure, ensure that the battery cart attendant clearly understands how you will signal for the plug to be removed.

HAZARD DUE TO THE POSITION OF EXTERNAL POWER PLUG

On some twins, the external power receptacle is located on the nose of the aircraft, close to one of the propellers. If this is the case, first start the engine furthest from the plug.

Bring the operating engine alternator on line, have the external power source removed, run the operating engine at about 1500 RPM and, after about a minute, start the second engine using the aircraft battery (which by now will have taken some charge and, in combination with the first engine alternator output, should provide sufficient power for starting). This procedure minimises the risk of possible injury to the external power attendant during plug removal.

If the external power plug is close to a propeller arc and must be used to start both engines, make sure the battery cart attendant is properly briefed on the prop hazard.

TAXIING

TAXIING SPEED AND WINGTIP CLEARANCE

Because you now have thrust from two engines, rather than one, a twin will taxi faster at the normal single-engine power setting. Additionally, you will normally have a greater wing span and the engine nacelles may limit your view of the wing tips, eg, Partenavia. All this means that you must taxi very slowly in the vicinity of possible obstructions, eg, building, fences or other aircraft.

The power used when taxiing will be a compromise between low RPM to control speed, but which may induce spark plug fouling, and a higher RPM which may require frequent brake application to limit your speed. For most twins, 900 - 1000 RPM is about right to maintain a reasonable taxi speed on a level, hard surface.

In any event, avoid using brakes against thrust to avoid brake overheating and premature brake pad/disc wear.

If there is any tendency to lead fouling of spark plugs at low RPM, the mixture may be leaned judiciously during taxiing to minimize the problem. But remember to place the mixture controls in the full rich position for run-up checks!

USE OF DIFFERENTIAL POWER

Differential power (and possibly differential braking) may be used to assist nose-wheel steering in tight turns, but make sure that engine RPM is reduced to normal and synchronised when taxiing straight ahead, so that differential (asymmetric) thrust is not fighting against nose-wheel steering.

CHECKS WHILE TAXIING

When taxiing in proximity to obstructions, don’t conduct taxi checks which require your attention on cockpit indicators and controls. Preferably, complete these checks either before taxiing, or at the holding point before the run-up checks. The only checks which need to be done while moving are the functional checks of gyro instruments, compass and tracking of the ADF indicator.

Check of Crossfeed Operation and Tank Selection

To verify complete fuel system operation, select cross feed on briefly while taxiing. Then select cross feed off and select the tanks which will be used for run-up and take-off — normally the main tanks — but consult the POH.

WARNING

NEVER TAKE-OFF USING FUEL TANKS WHICH HAVE NOT BEEN USED DURING THE ENGINE RUN-UP CHECKS

RUN-UP CHECKS

COMBINING RUN-UP AND PRE-TAKE-OFF CHECKS

Some POH checklists combine the engine run-up and pre-take-off checks. However, we advise against this practice because run-up checks may require movement of switches or controls to positions which would be wrong for take-off, and this is potentially hazardous. Therefore, we recommend that you complete the engine run-up checks before starting the pre-take-off checks.

RUN-UP CHECKS TOGETHER

Except for the feather checks, light-twin engines may be run-up and checked simultaneously; running up engines one at a time does place some strain on the nosewheel leg.

MAGNETO SWITCH OPERATION

With toggle or rocker-type magneto switches, get in the habit of using one finger (or finger and thumb) only to operate each switch in turn. This will help to avoid the possibility of switching off both magnetos at the same time, and may save an expensive repair if the unburned fuel ignites explosively in the exhaust system when the switches are hurriedly turned back on after the engine cuts!

ANALYSIS OF RPM DROPS DURING MAGNETO CHECKS

Magneto checks at about 65% power will give the best indication of ignition system performance. The propeller controls must be in the fine pitch (high RPM) position to ensure that action of the CSU attempting to maintain RPM does not mask an excessive magneto drop. In any event, use the RPM recommended in the POH.

If a magneto check reveals smooth engine operation but the RPM drop is excessive, this may indicate a mixture, rather than a magneto or plug, problem. In this case, lean the mixture cautiously and repeat the check. If the magneto drop is now within limits and the engine runs smoothly, the problem was a slightly over-rich mixture and the engine is healthy. This problem normally only occurs on carburetor-equipped engines.

Excessive RPM Drops

An excessive RPM drop with rough running is most likely to be a spark plug problem. Lead fouling may often be cured by running the engine at about 2000 RPM, both magnetos on and with the mixture leaned to just above the point where the engine starts to run roughly. Maintain this for 15 to 20 seconds. This procedure raises the combustion temperature to the point where the lead fouling the plug(s) may be burnt off. Return the mixture to rich and re-check the magneto drop. If this has not cured the problem, return to the ramp and have the problem checked by an Engineer.

Do not attempt a take-off with an excessive magneto drop hoping that the fouling (?) will clear at full power - the problem may be an internal magneto fault, which could lead to an engine failure just after take-off!

CHECK OF ENGINE INSTRUMENTS DURING THE RUN-UP

Having checked the magnetos, governors and the carburetor heat or alternate air as applicable (vital for IFR), and while still at relatively high power, check all the engine gauge indications - oil pressure, oil temperature, cylinder head temperature, EGT, fuel pressure, gyro vacuum/pressure. All should be normal and in the green range.

With fuel injected engines, check that the manifold pressures and fuel flows required to give the same RPM on each engine are not significantly different. If one engine requires more manifold pressure and indicates an apparently higher fuel flow (actually fuel pressure) to give the same RPM as the other engine, this is a fairly good indication of a blocked injector and not, as may be suspected by the apparently higher fuel flow indication, a rich mixture.

A blocked injector causes a higher fuel pressure in the fuel distributor, which shows as a higher fuel flow than normal! There would usually be some associated roughness, but this may be masked on a six-cylinder engine.

Whatever the cause, do not attempt a take-off before an engineer checks and rectifies the problem.

CHECK OF FEATHER OPERATION

Unless otherwise specified in the POH, the check of feather operation should not be done above 1500 RPM, as feather checks at higher RPM can impose high stresses on blade roots and blade bearings. Move the pitch levers forward out of feather before RPM falls below 1000; lower RPM places a heavy load on the engine. Also, check each feather operation separately, as some propellers move into feather very rapidly, or at different rates. Never attempt a take-off if the feather operation is not normal!

RUN-UP CHECKS AT TRANSIT STOPS

If on a multi-stage flight with intermediate, short duration stops, full prop governor checks are not necessary before every take-off. However, always conduct a magneto and feather check before every take-off (other than training touch-and-go landings with a qualified instructor or check pilot).

WARNING

DO NOT CONDUCT RUN-UP CHECKS WHILE TAXIING.

YOU CANNOT TAXI SAFELY AND OBSERVE RPM DROPS, TEMPS, PRESSURES, ETC.

THIS PRACTICE IS ALSO EXTREMELY HARD ON BRAKES.

PRE-TAKE-OFF CHECKS

These are the most important checks on every flight; your last chance to confirm that every control, switch and instrument indication is as it should be. Therefore, use the checklist!

PRE-TAKE-OFF SELF BRIEFING

The last checklist item before every take-off should be a self-briefing on what you will do in the event of an engine failure. The purpose of this self-briefing is to mentally prepare you for decisive, rapid action if an engine does fail; time lost in trying to decide what to do after the event can be fatal.

Engine failure considerations and procedures are covered fully in the Emergency Procedures Section.

LINE-UP CHECKS

Before starting the take-off roll, stop the aircraft momentarily on the centre-line, check that the compass agrees with the known runway heading (vital for IFR flight), select the transponder as appropriate and switch the pitot heat on for all IFR flights. This last item is not done earlier to avoid the possibility of burning out the pitot heater due to lack of cooling airflow.

TAKE-OFF

POWER APPLICATION

Many manufacturers advocate the application of full power and a check of RPM/manifold pressures before releasing the brakes. Certainly with turbo-charged engines (and particularly those without over-boost protection), the power should be advanced to about 30" before brake release (if possible and prudent) to allow for the relatively slow “spool up” of the turbochargers, and then advanced carefully but deliberately to maximum boost early in the take-off roll.

This will help to avoid over-boosting and minimise the time when your attention is split between engine gauges and control of direction as the aircraft accelerates.

Full Power Checks on Grass or Gravel

However, full power on the brakes may not be possible on a grass runway, and it certainly is not advisable on a gravel runway where significant damage may be done to the propellers by loose stones.

In these conditions, release the brakes and open the throttles as the take-off roll begins. In any event, full power should be achieved and both manifold pressure and RPM checked as being normal early in the take-off roll.

When full throttle/maximum boost pressure has been reached, place your fingers over the top and in front of the throttle levers to indicate and facilitate throttle closure if an engine fails before decision point.

MAXIMUM RPM CHECK ON THE TAKE-OFF ROLL

Unless taking off from a high altitude airfield or at high temperatures (high density altitude) with un-supercharged engines, the maximum RPM should always be achieved at full throttle.

At low density altitudes, if the governed RPM on either engine has not reached at least 100 below red line by about 50 knots, close the throttles and abort the take-off.

The engine is not developing full power or the propeller is not on the fine pitch stop. Whatever the cause, have an engineer check the problem before another take-off attempt. The fix may be a simple adjustment of the maximum RPM stop on the governor.

ROTATION SPEED

Provided there is no tendency for the aircraft to “wheelbarrow”, the aircraft should not be rotated for liftoff until at least the take-off safety speed (TOSS), as specified in the POH take-off performance chart. There are some aircraft, eg, Twin Comanche, which will tend to “wheelbarrow” if held on the ground until TOSS. In an aircraft with this characteristic, rotate at not less than 5 knots above Vmca (red line) and hold a shallow climb angle until TOSS is achieved at 50 feet.

INITIAL CLIMB ATTITUDE

Once TOSS is achieved, rotate the aircraft smoothly to 8-10 degrees nose up on the AH; the equivalent visual attitude for most aircraft is with the nose/instrument shroud on the horizon.

DECISION POINT NOT DECISION SPEED

Many multi-engine pilots have been taught to use a Decision Speed to determine the actions to be taken in the event of an engine failure on take-off, and this is usually taken to be the “Blue Line” speed.

Many of these pilots have also been taught to retract the undercarriage when this “Decision Speed” has been reached, in order to minimise drag, irrespective of the length of runway remaining.

In our opinion, a safer practice is to use a Decision Point rather than a Decision Speed. This point is where the pilot assesses visually that insufficient runway remains to land and stop the aircraft, and the undercarriage should not be retracted until this point is reached.

In aircraft with fixed undercarriage, the Decision Point can be signified verbally - “committed” - and/or by changing the position of the hand on the throttle, from fingers cupped over the throttles ready for immediate closure to palm behind maintaining full power.

A number of unnecessary accidents have occurred when pilots have elected to continue a take-off when an engine has failed after Decision Speed, with ample runway remaining for an abort but insufficient climb performance to continue the take-off and an asymmetric circuit.

The result has usually been that the aircraft decelerated to minimum control speed while the pilot was instinctively, but incorrectly, trying to remain airborne.

The physical movement of the undercarriage lever or changing the hand position on the throttles signifies the deliberate intention to continue, rather than abort, the take-off.

Although the selection of this Decision Point on each take-off is a matter of judgement, this judgement should be taught as part of multi-engine endorsement training. As a guide, it is normally when the departure end of the runway disappears under the nose in the initial climb attitude.

On a short runway, this will be almost immediately after liftoff. On a long runway, this decision point may not be reached until 100 - 200 feet after take-off (or even higher).

INITIAL CLIMB

Adjust the pitch attitude and trim to maintain maximum angle climb speed (Vx) until clear of obstructions. When through 1000 feet AGL and clear of all obstructions, set climb power and adjust the attitude to obtain/maintain the maximum rate climb speed (Vy) or cruise climb speed. Re-trim for this attitude and complete the after take-off checks appropriate to the type of aircraft.

CLIMB

The initial climb may need to be continued at maximum rate if required by ATC or for terrain clearance requirements in IMC. Once maximum climb performance is no longer a requirement, adjust the pitch attitude for a cruise climb and re-trim.

CRUISE CLIMB SPEEDS

Some manufacturers recommend a specific cruise climb speed, but there is nothing “magical” about this figure in terms of climb performance. We recommend setting and trimming for a pitch attitude which will give good visibility over the nose and an acceptable rate of climb, say, 500 feet per minute, until cruise altitude is reached, and accepting whatever IAS this achieves.

PROPELLER RPM SYNCHRONIZATION

Synchronise the engine RPM early in the climb. The technique I recommend is to regard one pitch lever as the “master”, setting this to give the desired indicated RPM. If the props are not synchronised as indicated by an audible “beat”, move the other “slave” pitch lever as necessary. If the “beat” increases in frequency, you’re moving the lever the wrong way!

Adjust the “slave” pitch lever until the “beat” disappears, then tighten the friction lock. If this is not done, engine vibration will often cause the controls to move slightly, requiring constant adjustment.

With normally-aspirated, ie, non-turbocharged, engines, you will need to advance the throttles as the climb progresses to maintain climb manifold pressure. I recommend a habit pattern which checks and adjusts manifold pressure each 1000 feet in the climb. At about 5000 feet density altitude the throttles will be fully open and manifold pressure (power) will then decrease as the climb continues.

MIXTURE CONTROL IN THE CLIMB

With fuel injected engines, the manufacturer may recommend leaning with the mixture control to give a specific fuel flow in the climb. On many fuel flow (pressure) gauges, these recommended climb fuel flows are marked in relation to altitude. If leaning is recommended in the climb, also monitor the EGT and CHT gauges as a crosscheck; fuel flow gauges can be inaccurate and an overly-lean mixture must be avoided at high power settings.

OPERATION OF COWL FLAPS

Most twins are fitted with cowl flaps to control cooling airflow through the engine nacelle. These are normally fully open in the climb, but in a cruise climb they may be partially closed to reduce drag provided cylinder head and oil temperatures are not near the top of the green range.

If the cowl flaps are partially closed in the climb, monitor these temperatures closely and open the cowl flaps fully if the temperatures approach the top of the green range.

CRUISE

The selection of cruising altitudes and cruise power settings is covered fully in Section 4 - Flight Planning and Performance

DESCENT

If terrain and ATC restrictions permit, plan your descent to give a comfortable rate of descent (5-600 feet per minute) at cruise IAS. If you wish to descend at higher speeds, don't exceed Vno (start of the yellow ASI arc) if the possibility of turbulence exists.

TURBULENCE AND MANOEUVRING SPEED

If turbulence is forecast or suspected for your descent, be aware of the manoeuvre speed (Va) for your weight. Remember that the Va shown in the POH may be for maximum AUW, and that Va decreases with decreasing weight. If you encounter unexpected moderate to severe turbulence in a descent, close the throttles and raise the nose to reduce to Va as soon as possible - the next sharp-edged (and possibly damaging) gust may be seconds away.

In the event of control difficulties caused by severe turbulence, lower the undercarriage. This will slow you down more quickly and will normally improve directional stability. If you encounter severe turbulence, don't be too concerned about maximum gear extension speed; better to risk some damage to the gear doors rather than risk over-stressing the primary structure.

If you are forced to over-speed the gear to avoid a possible over-stress in unexpected severe turbulence, leave it down for the remainder of the flight and have it inspected for possible damage after landing.

ENGINE HANDLING ON DESCENT

During a descent, the main concern is to avoid under-boosting, which can cause damage to crankshaft bearings, and to avoid rapid cooling, which can cause damage to cylinders. Higher powered engines are particularly at risk.

Cowl Flaps and Mixture Control

Unless otherwise specified in the POH, ensure that cowl flaps are closed during a descent, and **don't** richen the mixture during the descent. The additional fuel reduces combustion temperature and can aggravate the problem of excessive cylinder cooling. The mixture can be enriched at the end of the descent after increasing to cruise power.

Power Reduction with Turbochargers

With turbocharged engines, reduce the Manifold Pressure gradually during the descent, say, 2” each 1000 feet until the desired descent power is achieved.

RPM Reduction when Descending from High Altitude

With normally aspirated engines, cruising at relatively high altitudes above full throttle height will normally mean relatively low Manifold Pressures, probably in the 18" - 22" range.

In this case, reduce the RPM by about 300 to begin the descent rather than reducing an already low manifold pressure, provided this will not exceed the RPM/Manifold Pressure limits for your engines. This technique will provide a reasonable descent power while maintaining the Manifold Pressure needed to protect the engine against excessive cooling and under-boosting.

As the descent progresses, the Manifold Pressure will increase due to increasing air density, requiring throttle adjustment to prevent the possibility of over-boosting. At the end of the descent RPM can be increased to a more normal cruise value for instrument approach or landing.

Control of Speed in Steep Descents

If forced to make a steep descent because of terrain or ATC requirements, increase drag by lowering the gear or, in the case of high performance twins, extend approach flap to avoid excessive descent speeds, rather than reducing power below the desirable minimum.

CIRCUIT AND LANDING

CIRCUIT APPROACH PLANNING

Plan your approach to the airfield to arrive on downwind at the appropriate speed (normally top of the white arc) without the need to reduce the Manifold Pressure below 15". If arriving at a controlled airfield and cleared to join base or final, plan ahead to have all the before-landing checks completed and the aircraft configured early to avoid the possibility of a steep, fast approach.

USE OF FLAPS ON DOWNWIND

If conducting a normal circuit entry, a recommended technique is to lower approach flap (if not already extended for the descent) abeam the approach threshold. This reduces the number of configuration and trim changes needed on base and final, and improves “over the nose” visibility.

APPROACH PROFILE AND MINIMUM SPEED ON BASE

When ready to turn base, adjust the attitude and power to fly a constant descent angle profile from the base position to the round-out point. Maintain a minimum of target threshold speed (TTS) plus 10 -15 kts on base and lower the second stage of flap (if applicable).

FINAL APPROACH TECHNIQUE AND CHECKS

When stabilized on final (about 300 - 400 feet), conduct the final approach checks - gear checked down, maximum RPM, landing clearance or runway clear - lower the final stage of flap, re-trim and start a gradual reduction of IAS to the planned (TTS) as specified in the POH for the aircraft weight. As a simple alternative, the TTS should be the flap down stall speed (Vso - bottom of the ASI white arc) multiplied by 1.3.

Use the throttle to control IAS and the primary flight controls to control flight path - ailerons to maintain centre-line and elevators to maintain a constant descent angle (profile) to the round-out point.

Don’t go below the approach path on short final in the mistaken belief that a shallow final flight path to the end of the runway will somehow aid a smoother landing or reduce ground roll.

An engine failure on a “submarine” approach will cause a rapid reduction in airspeed, and you will probably need full power on the good engine to stay airborne - this is a classic “setup” for a loss of control in the worst possible situation, just above the ground!

THROTTLE HANDLING DURING THE LANDING

Close the throttles completely during the round-out. As with the shallow final approach myth, many pilots seem to believe that carrying some power through the flare and hold-off helps to achieve a smooth landing.

It rarely does, but the technique certainly extends the landing distance, which could be very embarrassing on a minimum length runway!

MINIMUM FIELD LENGTH LANDINGS

APPROACH PLAN AND PROFILE

Many pilots also seem to have a mistaken belief that a minimum field length landing requires a short, higher-than-normal approach. If anything, a good minimum field length approach and landing begins with a slightly delayed base turn and a longer final, giving the pilot plenty of time to establish the landing configuration early and to “stabilize” the approach at the correct speed and approach angle, properly trimmed.

POH LANDING DISTANCE CHARTS

The landing charts in the POH are for minimum field length landing distances. These charts assume that the correct TTS (Vso x 1.3) is achieved at 50 ft and the throttles then closed.

MINIMUM FIELD LENGTH APPROACH SPEEDS

The approach speeds specified in the POH are normally a function of landing weight, and they should be known and be used for all short-field landings.

Achieving these speeds at the recommended point of throttle closure (in the flare) ensures that adequate control will exist for a normal round out and hold-off, while still enabling the aircraft to be stopped in the specified landing distance.

LOSS OF LIFT ON THROTTLE CLOSURE

One point to bear in mind is that most twins will experience some loss of lift when the throttles are closed because of the reduction in air velocity over the wings behind the propellers, and there will also probably be a small trim change nose down. Both of these effects will require back pressure to maintain the desired flight path.

If preferred, the control input can be anticipated and assisted by carrying slightly more back trim on final than is needed, ie, slight forward pressure on the control wheel to maintain the desired attitude/approach path.

LANDING AND BRAKING TECHNIQUE

Don't be too anxious to get the nose wheel on the ground after touchdown. Lower the nose gently under positive control, and begin gentle but steady braking.

Once braking is begun on minimum field length runways, the control column should be held back to maximise the weight on the main wheels for increased brake effectiveness, and to relieve the load on the nose wheel. As the speed reduces, heavier braking can be applied if runway remaining is critical.

If the runway surface is slippery (grass/wet or both), the brakes should be "pumped" on and off to help prevent wheel "lockup" and skidding. As aircraft speed (and lift) decreases, the brake pedal pressure can be increased with each "pump".

CABIN PRESSURIZATION CONTROL

PRE-FLIGHT AND TAKE-OFF

The cabin pressurization controls are normally set before take-off. The pilot sets either the desired cruise cabin altitude or the planned cruise altitude plus 500 feet.

The air inlet duct valves are checked opened during the pre-start checks.

CLIMB

As the aircraft climbs, the cabin pressure will begin to increase and the regulating valve will control the exhaust flow to provide the selected cabin rate of climb. If the cabin rate of climb is either too fast or too slow, the pilot can adjust the rate with the rate control.

The cabin will eventually "level off" at the selected cabin altitude, which may be at sea level. However, if the cabin pressure reached the maximum allowable value during the climb the cabin altitude will increase as necessary to maintain this value, irrespective of the selected cabin altitude.

DESCENT

Pressurization Control Panel Setting

Before starting the descent, the pilot selects the destination airfield circuit height plus 500 feet.

As the aircraft descends, the pilot may adjust the cabin descent rate, if necessary, to provide a comfortable rate of pressure change.

Cabin Vs Actual Altitude During the Descent

As the cabin altitude will normally be well below the actual cruising altitude, the cabin altitude will decrease ahead of the aircraft's actual altitude, even allowing for a high aircraft descent rate.

The regulating valve is designed so that cabin pressure can never be less than the outside air pressure - the cabin structure is designed to withstand only positive pressure loads! This means that the cabin altitude can never be above the actual aircraft altitude.

If during a very high rate of aircraft descent the actual altitude “catches up” to the cabin altitude, the cabin rate of descent will increase to match the actual descent rate, with a corresponding affect on your ears, and those of any passengers.

SECTION 3

EMERGENCIES AND ABNORMAL OPERATIONS

MULTI-ENGINE FLIGHT MANUAL FOR PROFESSIONAL PILOTS

SECTION 3 – ABNORMAL OPERATIONS AND EMERGENCYPROCEDURES

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INTRODUCTION

A multi-engine aircraft, like any single, is designed, built and certificated to rigorous standards. The structure of the aircraft should never fail if it is flown within the specified limits, and maintained as required by the manufacturer and the certifying authority.

However, mechanical and electrical components may occasionally fail or behave abnormally. Most importantly, all pilots and engineers are subject to human error, and this human factor is, unfortunately, the cause of most emergencies and abnormal operations.

The ability of pilots to successfully handle these rare situations and land safely is directly dependent on:

a. their knowledge of an aircraft's systems,

b. their initial and recurrent training in the correct procedures, and

c. most importantly, their professional attitude and airmanship.

The information contained in this manual is applicable to light twins in general. However, system design and recommended operating procedures differ between manufacturers and models. Pilots must therefore refer to the POH applicable to their aircraft for specific emergency and abnormal operation procedures.

ENGINE FAILURES

The principal reason for fitting more than one engine to an aircraft is to ensure the safe continuation of flight in the event of an engine failure, provided that the correct procedures and techniques are used by the pilot.

The most critical time for an engine failure is during the take-off and the initial climb to a height above obstructions in the vicinity of the departure field.

Before learning specific procedures and techniques, the pilot of a twin-engine aircraft should fully understand the aerodynamic effects of a wing-mounted engine failure on aircraft control and climb performance. These effects govern the procedures and techniques which should be used in the event of an engine failure.

ASYMMETRIC CONTROL

EFFECT OF ASYMMETRIC FORCES

Yaw

If an engine fails, the thrust force, which normally is the combination of the thrust forces from each propeller and acts symmetrically through the Centre of Gravity (CofG) of the aircraft, is displaced, ie, the thrust becomes asymmetric. The displaced thrust force creates a yawing moment around the CofG. This yawing moment is aggravated by the asymmetric drag created by the windmilling propeller on the failed engine.

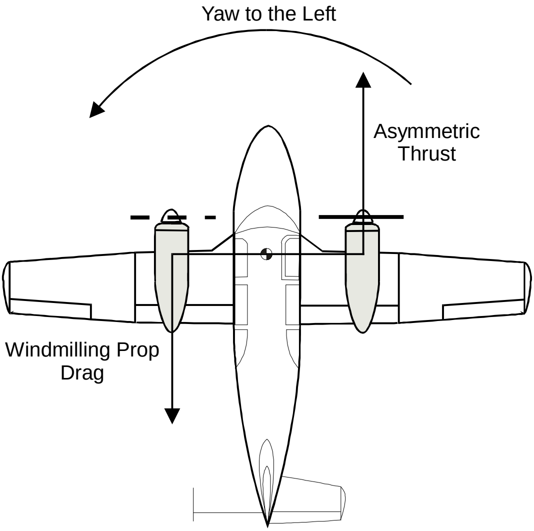

Figure 3 - 1. Yaw due to Asymmetric Thrust and Drag

Roll

The yaw caused by an engine failure has a secondary effect. As the aircraft yaws, the "outboard" wing is accelerated which creates more lift on that wing, and the aircraft rolls towards the failed engine, ie, in the direction of the yaw.

Figure 3 - 2 illustrates that the roll (which is usually the effect most evident to the pilot) is aggravated because the reduced slipstream over the wing behind the windmilling propeller, reduces the lift on that wing

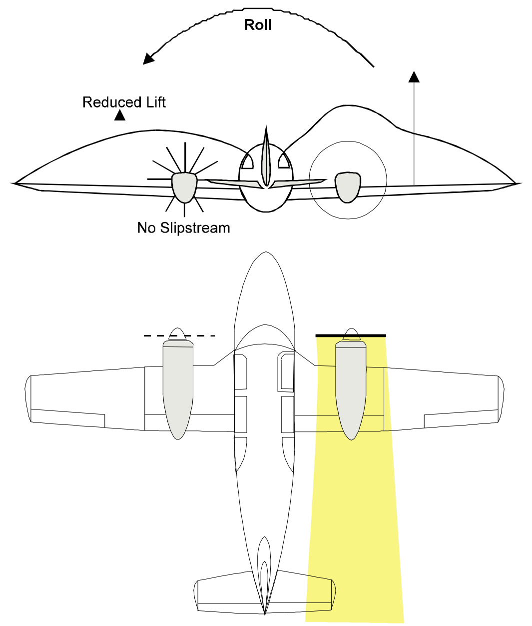

Figure 3 - 2. Aggravation of Roll due to reduced Slipstream

CONTROL OPTIONS AVAILABLE

To counter these effects, the pilot must make control inputs to re-establish the desired flight path. A number of options are available.

Throttle Movement Only

Virtually symmetrical thrust can be restored immediately by fully closing both throttles. While this will overcome the yaw and roll, it will also negate the advantage of having two engines, and will effectively turn the aircraft into a glider.

This may not be the most desirable flight condition, especially just after take-off. However, there can be circumstances in which this is the only safe option available.

Rudder Only

The yaw caused by asymmetric thrust and drag is the basic cause of the control problem. Therefore, the yaw can be countered by using rudder only, with the wings held level with a small aileron application. The aircraft is now subject to a rudder side-force which, in conjunction with the thrust from the “live” engine, will cause a slip towards the failed engine.

As a result of this slip the relative airflow will now be at an angle to the aircraft centre-line, and this “angled” relative airflow will generate a fuselage (keel surface) side-force, acting behind the centre of gravity and adding to the asymmetric thrust and drag moments.

With the wings level, this force can only be countered by applying more rudder. Eventually, the rudder and fuselage side forces will be equal, and the aircraft will be in equilibrium, maintaining a constant heading but slipping towards the failed engine.This slip causes an increase in form drag, which will degrade the aircraft’s performance. In this condition the balance ball will be central.

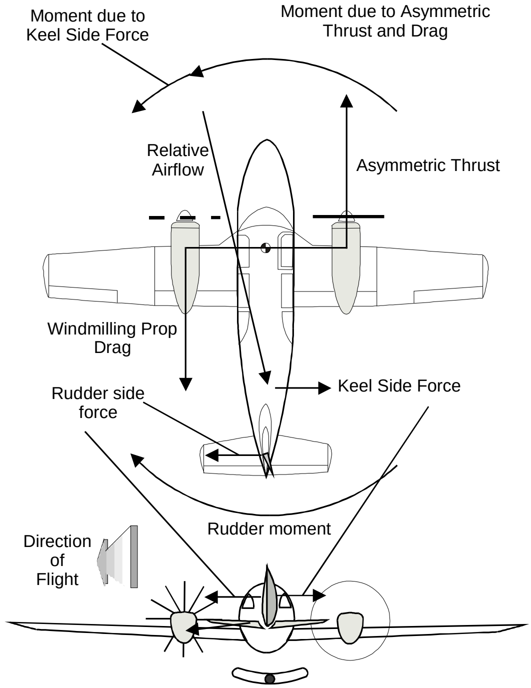

Figure 3 - 3. Forces and Moments when Rudder Only is Used

Aileron Only.

If the aircraft is banked towards the operating engine without any rudder application, the combination of the operating engine thrust force and the horizontal component of lift will cause a slip towards the operating engine. This slip will cause the relative airflow to strike the side of the fuselage and fin (keel surface) at an angle and will create a side force which, acting behind the centre of gravity, will counter the asymmetric thrust and drag moments.

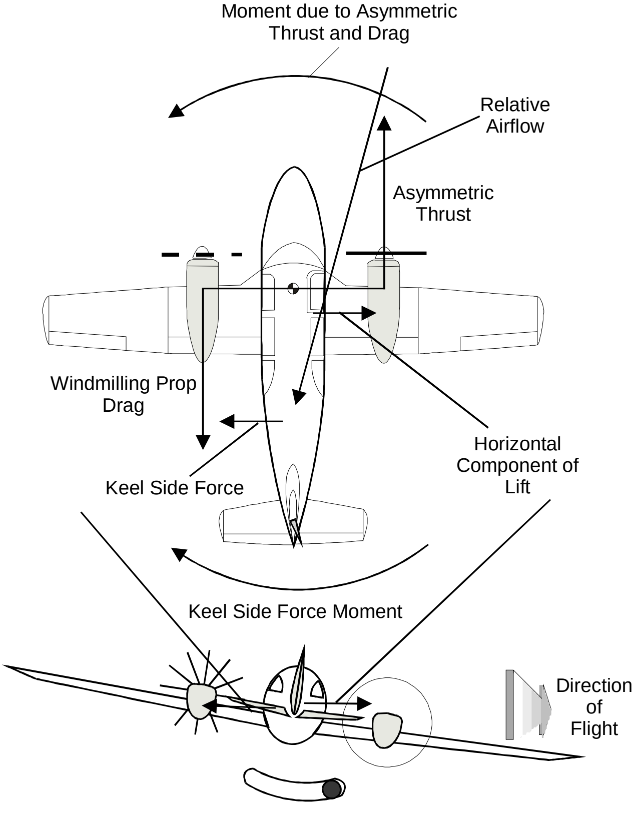

Figure 3 - 4. Forces and Moments when Aiuleron Only is Used

Provided sufficient bank is used, the horizontal component of lift will be equal to the fuselage side force, and the aircraft will now maintain a straight flight path without any rudder applied, but with a significant amount of slip towards the operating engine. Again, this slip will cause an increase in form drag. In this condition the balance ball will be well displaced towards the operating engine.

The use of aileron only to control the aircraft's heading after an engine failure is not recommended because:

a. the slip angle required could approach the tail fin stalling angle - if a fin stall occurred there would be an immediate loss of control; and

b. the amount of aileron deflection needed to hold the required bank angle may leave little in reserve to turn the aircraft towards the operating engine, if that were necessary to avoid obstructions.

Rudder and Aileron

If rudder is applied to stop the yaw and then about 2 - 3 degrees of bank is applied towards the operating engine, the horizontal component of lift will balance the rudder side force. The aircraft is now not slipping, and there is no fuselage side force to be countered by additional rudder. In this "zero-slip" condition the balance ball will be displaced about half to one ball-width towards the operating engine.

This combination of control inputs has a number of significant advantages:

a. less rudder deflection is required to stop the yaw, leaving more available to maintain directional control if speed decreases;

b. the absence of slip minimises form drag, and this has an important effect on aircraft performance; and

c. the ability of the pilot to control the position of the balance ball is a direct indication that control is still possible.

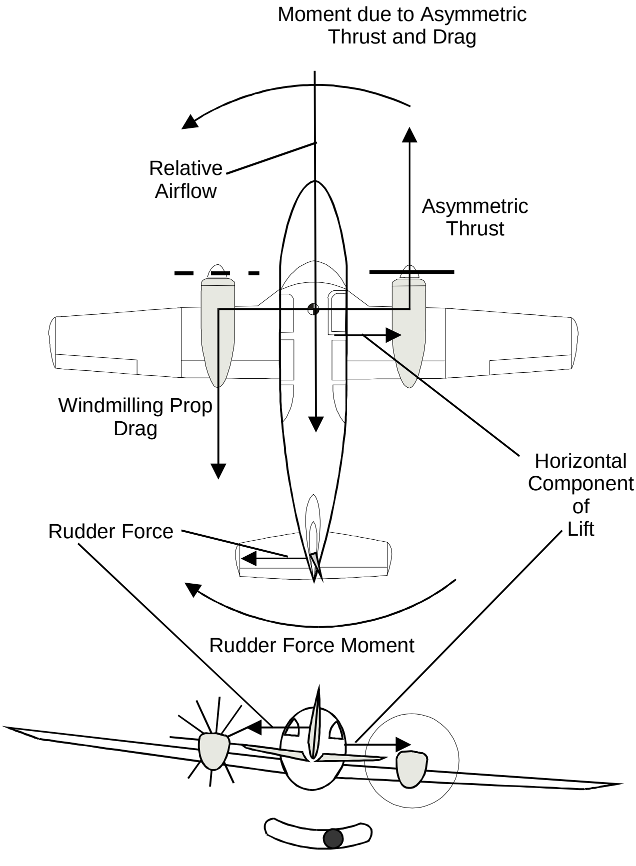

Figure 3 - 5. Forces and Moments when Rudder and Aileron are used

MINIMUM CONTROL SPEED

REDUCED RUDDER EFFECTIVENESS

If level flight is maintained following an engine failure, the loss of thrust will cause the airspeed to decrease and, as a consequence, there will be a decrease in rudder effectiveness.

Increasing rudder deflection will therefore be required as speed falls to counter the yaw caused by the asymmetric thrust/drag moments.

Depending on the amount of thrust available from the operating engine, the speed may decrease until the rudder will be fully deflected and below this speed the pilot will be unable to maintain directional control unless either:

a. the thrust of the operating engine is reduced, and/or

b. speed is increased by lowering the nose to improve rudder effectiveness.

Either or both will mean a descent to maintain control, and if close to the ground, this will almost certainly result in a forced landing straight ahead. However, this is far more preferable than loss of control at low altitude!

An understanding of the factors which affect this minimum control speed is essential, and these factors are discussed in the following paragraphs.

FACTORS AFFECTING MINIMUM CONTROL SPEED

Critical Engine

The magnitude of the yawing moment caused by asymmetric thrust is directly proportional to the thrust (force) being generated by the operating engine and the distance (arm) of the thrust line from the Centre of Gravity.

At normal cruising speeds with relatively low angles of attack, the thrust lines from the engines can be considered to act through the propeller shafts, ie, each thrust force will be the same distance from the centre of gravity.

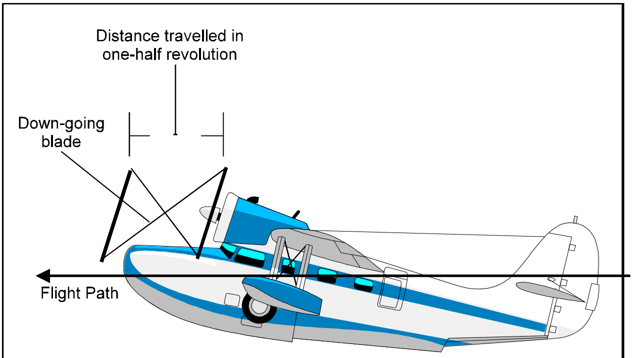

Figure 3 - 6. Effect of High Angle-of-Attack on Prop Blade realtive velocity

However, when an engine fails the loss of thrust and increase in drag will cause the aircraft to decelerate, requiring an increased angle of attack to maintain level flight. At high angles of attack, the propeller discs are no longer at right angles to the flight path, ie, the relative airflow.

In this condition, the down-going propeller blades are at a higher angle of attack and a higher relative velocity than the up-going blades, and the thrust force is displaced from the propeller shaft. This is the so-called “P-factor” which contributes to the take-off swing tendency in tail-wheel aircraft.

If both engines on a twin rotate in the same direction (clockwise in standard American engines) and the aircraft is at a relatively high angle of attack (slow speed), the thrust line of one engine (normally the right) will be further from the centre of gravity than the other.

A failure of the engine which has its thrust line closest to the centre of gravity will cause the greatest yaw, and therefore require the greatest rudder deflection. An engine which generates the largest yawing moment if it fails is termed the “critical” engine.

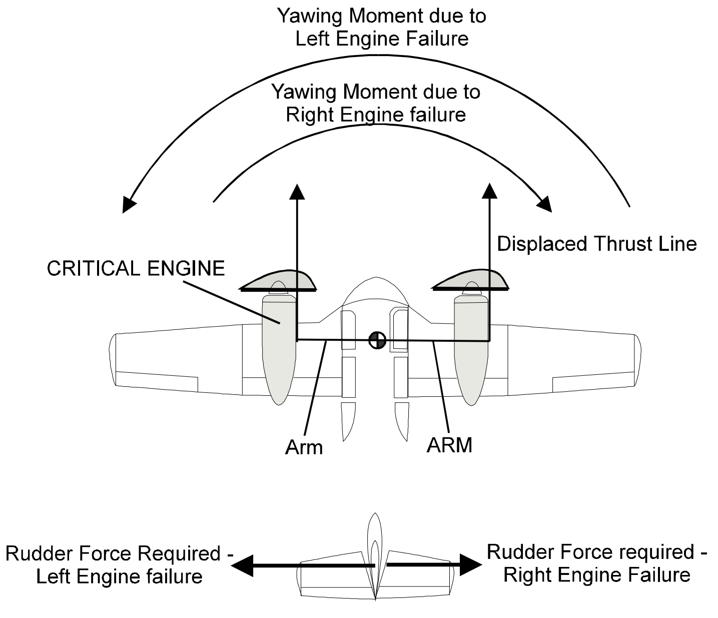

Figure 3 - 7. Variation of Yawing Moment with Critical Engine

To overcome the problem of a “critical engine” some manufacturers install counter-rotating engines so that the down-going propeller blades are closest to the centre of gravity. This minimises the yawing moment caused by asymmetric thrust at high angles of attack, and also means that neither engine is “critical”.

Thrust Available

An engine failure when both engines are delivering maximum available power (maximum available thrust) will result in the greatest yawing moment. Because engine power output in non-turbo-charged (normally aspirated) engines decreases with increasing density altitude, the greatest yawing moment due to asymmetric thrust will occur at sea level.

Centre of Gravity Position

The moment created by rudder deflection to counter the yaw of asymmetric thrust and drag depends not only on the side force created by rudder deflection, but most importantly on the distance (arm) of that force from the Centre of Gravity.

If this is at the aft limit, the rudder arm will be at a minimum, and a greater rudder deflection will be needed to stop the yaw. Figure 3 - 8 illustrates this effect.

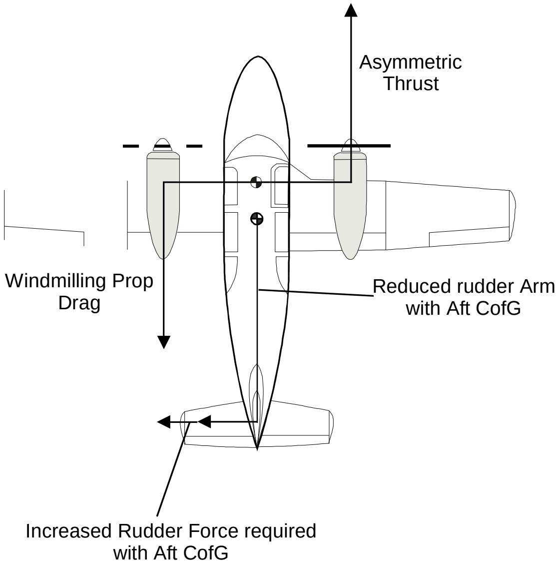

Figure 3 - 8. Effect of Centre of Gravity Position on Rudder Force Required

Flap

The effect of flap extension on minimum control speed depends largely on the control technique being used, ie, rudder only, aileron only or rudder and aileron. If there is zero slip (rudder and aileron with 2 - 3° bank), the extension of flap will have no effect on minimum control speed.

However, the increased drag from extended flaps will hasten the approach of the minimum control speed.

Undercarriage Position

As with flap, the effect of extended landing gear on the minimum control speed depends on the control technique being used. In a zero-slip condition, extended landing gear will have no effect on minimum control speed

However, extended landing gear will cause an increase in drag and hasten the approach of minimum control speed.

Extended undercarriage and gear doors will increase the aircraft's keel surface. This will help to dampen the rate of yaw following an engine failure and should give the pilot fractionally more time to make the required corrective control inputs.

Cowl Flap Position

Extended cowl flaps add to form drag and, as for extended flap and undercarriage, will affect the minimum control speed to a small extent.

Windmilling Propeller

A windmilling propeller approximately doubles the form drag, and increases the total drag by about 15 % at normal climb speeds. The amount of rudder deflection required to maintain directional control after an engine failure is largely due to this asymmetric drag.

Therefore, feathering the windmilling propeller is a priority consideration in relation to minimum control speed, apart from the considerations of climb performance.

Bank Angle

Banking an aircraft towards the operating engine reduces the amount of rudder deflection needed to counter the yaw caused by asymmetric thrust and drag. The use of bank therefore means that additional rudder deflection is available to maintain directional control as speed reduces.

Each one degree of bank angle will reduce the minimum control speed by about three knots; the lowest control speed will be achieved using about 10 degrees of bank. However, bank angles beyond this value increase the minimum control speed, and can cause a fin stall, with dramatic loss of control.

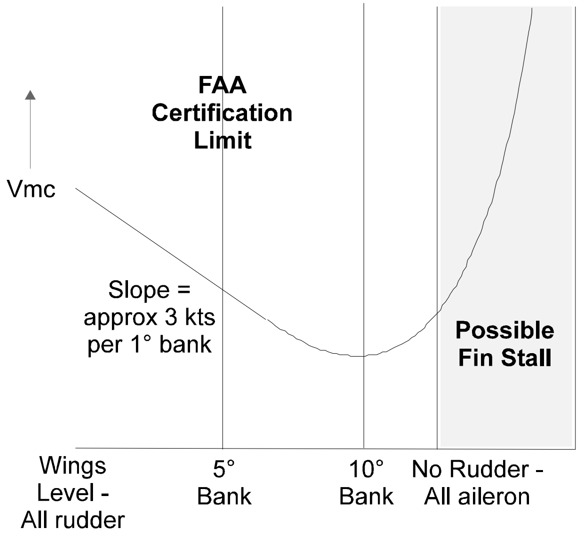

Figure 3 - 9. Effect of Bank Angle on Vmc

The effect of bank angle is particularly noticeable in some aircraft. For example, in the Piper Seminole full rudder deflection with wings level is reached at about 80 - 85 kts, but this reduces to about 58 kts when a prudent amount of bank is applied, ie, not more than 10° maximum. It is most important to appreciate this bank angle effect.

While there may be some reluctance to bank an aircraft when close to the ground, it may be the only means of maintaining directional control if airspeed is allowed to decrease while attempting to remain airborne.

VMC

The minimum speed at which directional control can be maintained with full rudder deflection is designated Vmc. This speed is established by a manufacturer under criteria specified by the Certifying Authority, taking account of the factors discussed above. For American aircraft Vmc must not be more than 1.2 x the Stall Speed (Clean) at maximum Take-off Weight.

VMC CRITERIA

The Vmc as determined by the manufacturer is marked on the airspeed indicator (ASI) of twin-engine aircraft by a red radial line. For aircraft certificated by the American FAA, the criteria used to determine Vmc are as follows:

a. Failure of the “critical engine”,

b. Engine controls set for take-off or maximum available power,

c. the most unfavourable centre of gravity (within limits),

d. The aircraft trimmed for take-off,

e. The maximum allowable sea-level take-off weight which permits c,

f. Flaps in the take-off position,

g. Landing gear retracted,

h. Cowl flaps in the take-off position,

i. The propeller of the inoperative engine:
    (i) windmilling, or
    (ii) feathered, if the aircraft is fitted with an auto-feathering device

j. The aircraft airborne and out of ground effect,

k. No more than 150 lbs of force required to maintain full rudder deflection, and

l. A maximum of five degrees of bank towards the operating engine.

These criteria reflect a “worst case” situation, ie, a complete engine failure immediately after take-off.

Although the criteria in an actual situation may be different from the test criteria, a pilot should never assume that the actual Vmc will be lower than that shown on the ASI. There is no safe way for the average pilot to determine what the effects of changes in the criteria may be. The initial determination of Vmc is done by highly experienced test pilots, and no allowance is made for the delay of control inputs that would almost certainly occur in the case of the average pilot faced with an unexpected engine failure.

The bottom line is that the published Vmc must be regarded as an absolute limit, irrespective of differences between actual conditions and Vmc test criteria. A pilot should never allow the airspeed to approach the Vmc red line while airborne with a real or simulated engine failure and a windmilling propeller.

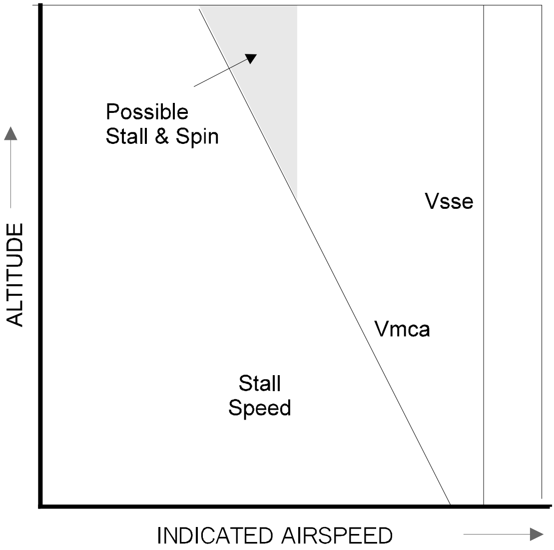

Figure 3 - 10. Variation of Vmca and Stalling Speed (Vso) with Altitude

VMC AND PRACTICE ENGINE FAILURE DEMONSTRATIONS DURING TRAINING

Vmc Demonstrations

Engine power and thrust decrease with increasing altitude in aircraft fitted with normally aspirated engines and, therefore, Vmc in these aircraft decreases as altitude decreases. However, as shown in figure 3 - 10, the stalling speed does not!

Vmc demonstrations during training are normally conducted at altitudes of about 3,000 - 4,000 feet AGL. Unfortunately, there have been a number of accidents in past years when instructors have attempted to demonstrate Vmc effects down to the sea level Vmc speed and a stall has occurred first - a stall with full asymmetric power and full rudder deflection can lead to a rapid spin entry.

Therefore, an instructor or approved pilot will normally use some artificial means to increase the safety margin while still enabling a realistic demonstration of the effects of Vmc to be seen.

These may include:

a. the extension of maximum lift flap to reduce the stalling speed,

b. maintaining wings level rather than using the allowable five degrees of bank, so as to artificially raise the Vmc, and/or

c. with instructor foot pressure limiting the rudder deflection available to simulate full rudder deflection at a speed safely above Vmc.

SAFE SINGLE-ENGINE SPEED

Most manufacturers specify a minimum speed below which a simulated engine failure should not be initiated in training. This is called the Safe Single-Engine Speed (Vsse).

A pilot should not practice simulated engine failures unless accompanied by a qualified instructor or a CAA-approved training pilot.

ASYMMETRIC PERFORMANCE

Retaining control of an aircraft following an engine failure must be a pilot’s primary concern.

However, the next most important consideration is performance, specifically climb performance. Accident analysis shows that loss of climb performance rather than loss of control is a primary cause of terrain impact following an engine failure.

CLIMB PERFORMANCE THEORY

To understand the effect of an engine failure on climb performance, a short revision of climb performance theory is needed.

Thrust Horsepower - Available, Required and Excess

Climb performance, whether with symmetric or asymmetric thrust, depends on many factors, but all of them are concerned with the excess of Thrust Horsepower (THP) Available . This excess is the difference between the THP required to maintain level flight at any speed, and the THP which is available from the engine/propeller combination at that speed.

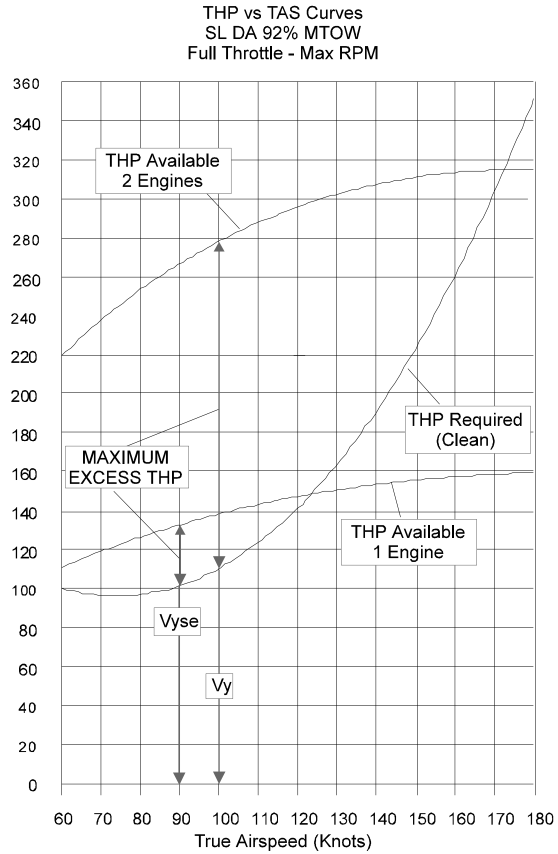

Figure 3 - 11. Typical Twin Engine Performance Chart

Best Rate of Climb Speeds

Although failure of one engine in a twin will mean a loss of only 50% of THP available, the loss of excess THP available to climb may be as high as 90%!

Figure 3 - 11 shows the THP Available and Required curves for a typical light twin with both engines operating, and with one engine inoperative The graph shows that while there may be sufficient Excess power available at the Best Rate of Climb Speed (Vy) to achieve above 1,000 feet per minute rate of climb on two engines at sea level, this may be reduced to climb rates in the order of only 100 - 200 feet per minute or less at the Single-Engine Best Rate of Climb Speed (Vyse).

With only one engine operating, the speed range over which any excess THP is available to climb may be small, and it is therefore essential that an aircraft with one engine inoperative is flown smoothly, at a pitch attitude (angle of attack) which will produce maximum climb performance. The speed which corresponds to this angle of attack is established by the manufacturer at maximum weight at sea level in ISA conditions with the aircraft clean, and is marked on the airspeed indicator as a Blue Radial Line.

Single engine rate of climb performance therefore depends on maximising the excess THP available. Provided that the operating engine controls are set for maximum available power, there is little the pilot can do about the Maximum THP Available.

Drag and THP Required

However, the THP Required in level flight is directly related to total drag, and the greatest excess of THP will therefore be achieved by minimising drag. Apart from maintaining a pitch attitude which will give the required Vyse, minimising drag is the only way a pilot can achieve maximum single-engine climb performance.

MAXIMUM ANGLE OF CLIMB

Although Rate of Climb is an important aspect of asymmetric climb performance, terrain clearance following an engine failure in the initial climb after take-off is more dependent on achieving and maintaining the Best Angle of Climb.

While best Rate of Climb is achieved by maintaining the speed for maximum excess THP, the best Angle of Climb is achieved by maintaining the speed which gives the maximum excess thrust under the prevailing conditions of aircraft weight, configuration and density altitude.

The all-engines-operating Best Angle of Climb Speed is designated Vx; the asymmetric Best Angle of Climb Speed is designated Vxse.

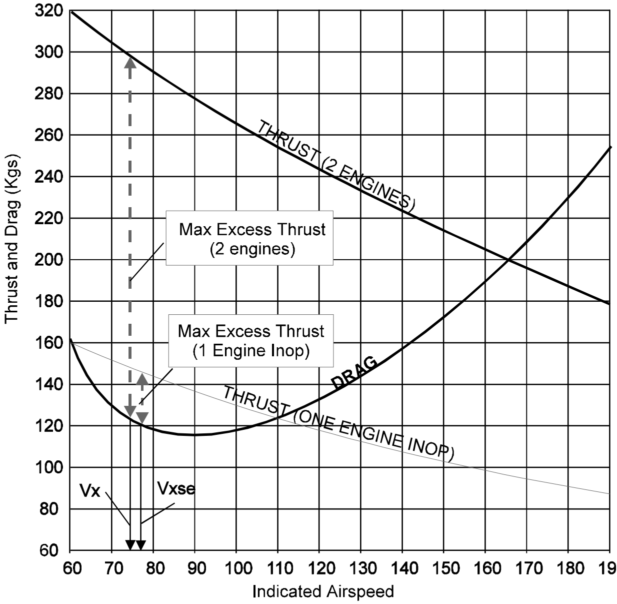

Figure 3 - 12. Comparison of Typical Thrust and Drag Curves - Normal and Asymmetric

Figure 3 - 12 shows the values of thrust and drag for a typical light twin in a clean configuration at maximum AUW and at Sea Level in the ISA. The graphs shows thrust with all engines operating and with one engine inoperative and the propeller feathered.

There is significant excess thrust available with all engines operating at maximum power. However, the excess thrust falls dramatically when one engine is inoperative.

A common drag curve is shown for both normal and asymmetric power situations. Higher drag values could be expected in an asymmetric situation unless all drag reducing measures are taken.

A graphic comparison between Best Angle and Best Rate of Climb speeds can be shown if Rates of Climb are plotted against IAS for both normal and asymmetric power situations.

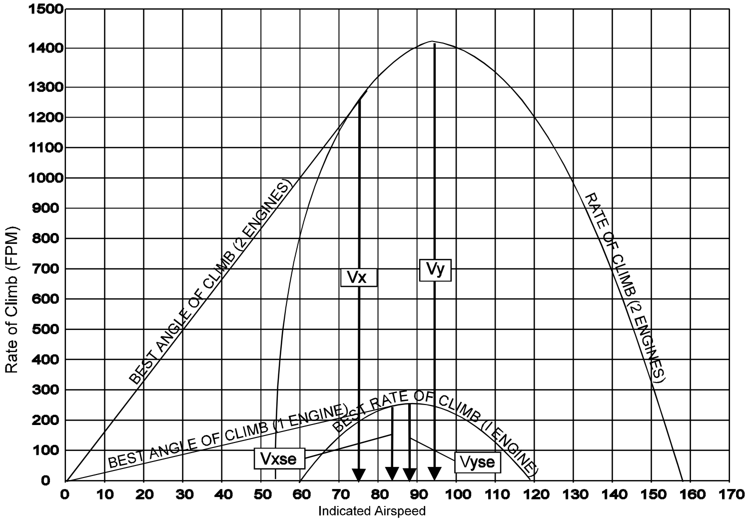

Figure 3 - 13. Comparison between typical Rates and Angles of Climb - Normal and Asymmetric Power

Figure 3 -13 shows the relationship between Best Angle and Best Rate of Climb for a typical light twin in the clean configuration, at maximum AUW and at Sea Level in the ISA. All-engines-operating and one engine inoperative (propeller feathered) data is shown.

A line drawn from the Zero speed origin of the graph tangent to the Rate of Climb envelope represents the Best Angle of Climb, ie, the maximum altitude gained in the least distance, and the point at which the tangent occurs is the Best Rate of Climb speed. Typically, it is less than the Best Rate of Climb Speed (Vyse).

Angle of Climb relative to the terrain is increased with a headwind while Rate of Climb is unaffected by wind.

Like Vyse, Vxse decreases with a reduction in weight, but increases slightly with increasing Density Altitude.

Whether a positive climb performance can be achieved following an engine failure in the initial climb after take-off depends on whether the flight has been planned professionally and the correct procedures and techniques are used!

Following is a discussion of the factors which affect asymmetric performance; most are also those which affect minimum control speed.

FACTORS AFFECTING CLIMB PERFORMANCE

Effect of Altitude

As density altitude increases, the power output of a non-turbo-charged engine and therefore the Maximum THP Available decreases until there is little or no excess THP available to climb. When the density altitude is reached where no excess remains, the aircraft has reached it’s Absolute Ceiling.

When the excess THP has reduced to the point where the rate of climb with both engines operating has fallen to 100 feet per minute, the aircraft has reached it’s Service Ceiling - typically about 20,000 feet.

However, with one engine inoperative, the Service Ceiling is reached when the rate of climb has fallen to 50 feet per minute, and this may be as low as 5,000 feet density altitude. Therefore, an aircraft which loses an engine while cruising at, say, 10,000 feet will have no climb performance and must descend until the single-engine ceiling is reached.

Remember that density altitude is a function of air temperature, so that a single-engine service ceiling of 5,000 feet density altitude may translate to an actual altitude much closer to sea level in summer!

Reduction of Vyse with Altitude

Actual Vyse decreases with increasing density altitude. As a rule-of-thumb, the “Blue Line” speed marked on the airspeed indicator may be reduced by 1% for every 1000 feet of density altitude above sea level to achieve maximum single-engine rate of climb.

However, the Angle of Attack (Pitch Attitude) to achieve Vyse will be the same at all altitudes, ie, if 8 degrees nose-up gives the indicated “Blue Line” speed at sea level with maximum available power on the operating engine, the same pitch attitude will give the best single-engine Rate of Climb at any altitude, although the indicated airspeed will be less than “Blue Line”.

Effects of Configuration and Aircraft Attitude

Configuration changes have a significant effect on total drag. In the event of an engine failure, a pilot’s main concern, after establishing control of the aircraft’s flight path and ensuring that the appropriate power is selected on the operating engine, must be to configure the aircraft and establish the attitude for minimum drag.

Windmilling propeller

The greatest drag contributor following engine failure is a windmilling propeller. Therefore, the propeller should be feathered as soon as possible after a total engine failure.

However, before moving a pitch lever to the feathered position, a pilot should identify and confirm which engine has failed, and be certain that the apparently failed engine is providing no power.

Undercarriage.

Although not the main contributor to drag following an engine failure the undercarriage, if extended, is easily retracted by the simple movement of the gear lever.

Importantly however, the undercarriage retraction cycle may actually increase drag as wheel fairing doors open. If this is the case, a manufacturer may recommend that the gear not be retracted until other drag reduction, eg, propeller feathering, has been accomplished. The Piper Navaho/Chieftain aircraft are in this category.

Some aircraft use an engine-driven hydraulic pump for gear operation, and only one pump may be fitted. If the engine on which the hydraulic pump is fitted is the one which fails and the propeller is feathered before the gear is fully retracted, the pilot will have to use the hand pump to complete the retraction cycle. This is not a desirable chore for a busy pilot at this time!

Flaps

Full flap deflection causes significant drag, but full flap will normally only be extended on final approach after a landing is assured. Flap retraction from the fully extended position should only be of concern if a single-engine missed approach is attempted on late final, and this is definitely not recommended as a normal procedure!

For take-off, most manufacturers recommend no flap extension, even for short- or soft-field takeoffs. Therefore, flap retraction is rarely a consideration when minimising drag after an engine failure after take-off.

Where manufacturers do recommend maximum lift flap for take-off, eg, Partenavia, this degree of flap extension does not contribute significantly to the total drag, but it’s retraction will cause a loss of lift and possibly sink, and therefore may be delayed until later in the drag reduction process.

In some aircraft, eg, the Twin Otter, the manufacturer recommends the extension of maximum lift flap after an engine failure. This flap extension increases wing drag but the pitch attitude with flap extended **reduces** fuselage drag to a greater extent.

Cowl Flaps

Although the cowl flaps on some aircraft do create a relatively significant amount of drag and should be retracted if absolute maximum climb performance is necessary, this should be delayed until the end of the drag reduction process.

Sideslip Drag

Although the immediate and instinctive control inputs after an engine failure are to stop the yaw and level the wings, the aircraft will be slipping with an increase in form drag. Although up to 10 degrees of bank will provide maximum reduction in Vmca, only about 3 degrees of bank towards the operating engine, with a reduction of rudder deflection to hold the balance ball displaced about one ball-width from centre, is needed to eliminate slip and maximise climb performance.

Therefore, the amount of bank to apply will depend on the immediate priority - maintaining control or maximising climb performance.

Even when turning, using the rudder to maintain a balance ball displacement of about half to one ball width towards the live engine will maintain the zero-slip condition and minimise the form drag.

Pitch Attitude

When an engine fails, the aircraft nose will fall below it’s trimmed attitude, in addition to the yaw and roll. This is because the aircraft speed will decrease and, for aircraft without a “T-tail”, there will be a reduction in propeller slipstream over the tailplane. This nose drop will require an elevator control input, and the pitch attitude should be selected which will provide Vyse.

For most light twins, the attitude is about 6 - 8 degrees nose up; visually, the instrument panel shroud will typically be on the horizon.

EFFECT OF WEIGHT

Weight variations have a significant effect on climb performance. As weight increases, more lift is needed to maintain level flight at any particular speed, and this means a higher Angle of Attack. In turn, this means more induced drag.

The THP required for level flight is directly related to drag, so that any increase in drag will move the THP Required curve upward and closer to the maximum THP Available curve, giving less excess THP available to climb. The effect is most pronounced at lower speeds where induced drag is a major factor.

Effect of Weight Variations on Vyse

The “Blue Line” speed marked on the ASI is for maximum AUW. The speed may be reduced by approximately 1 knot for each 50 kgs below this weight to ensure maximum single-engine climb performance.

Weight Limitations

The CASA may specify take-off weight limitations to ensure adequate single-engine climb performance for IFR operations.

Theoretically, an aircraft should be able to meet the CASA single-engine climb performance requirements provided it is operated within any weight limitations specified in the POH.

However, CASA certification is based on data which makes no allowance for degradation of maximum continuous power which will normally occur through wear between engine overhauls. Therefore, you should be aware that the actual single-engine climb performance may be less than the certification requirements.

The CASA climb performance requirements and the method for determining a maximum take-off weight which will enable safe single-engine flight is described in Section 4 - Flight Planning and Performance.

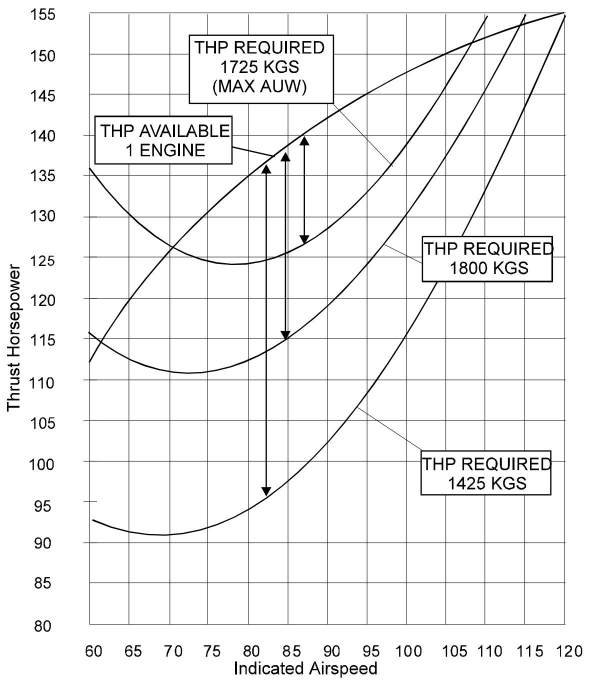

Figure 3 - 14. Effect of Weight on Climb Performance

Fuel Quantity Before Flight

In single-engine aircraft, it is common practice to load the maximum fuel possible without exceeding maximum take-off weight. If an engine failure occurs in a single-engine aircraft, there is no option but to execute a forced landing.

In twin-engine aircraft, however, continued flight to a safe landing is possible following an engine failure provided:

a. the correct procedures are followed, and

b. some climb performance (or at the very least, level flight) is available.

Weight has a significant effect on climb performance and, apart from aircraft attitude, is the only factor over which the pilot has control. Therefore, to ensure the best possible climb performance in the event of an engine failure, the pilot of a multi-engine aircraft should limit fuel weight before take-off to the minimum required for safe flight, including reserves.

There may be reasons why a pilot might want to carry a greater fuel load than absolutely necessary, eg, fuel availability or the cost of fuel enroute.

However, a prudent twin-engine pilot will limit the fuel weight at take-off as much as possible, knowing that any unnecessary weight will degrade climb performance if an engine fails.

This aspect is covered fully in Section 4 - Flight Planning and Performance.

ENGINE FAILURE PROCEDURES

The engine failure procedures and techniques described in this Section may be slightly different from those with which you are familiar, or those which you may have heard discussed by other pilots. However, they are based on logic and the experience of the authors.

URGENCY OF ACTION

The speed with which immediate engine failure procedures must be completed depends on the phase of flight during which an engine fails, and on the nature of the failure.

An engine failure immediately after liftoff requires immediate and correct action by the pilot, with no time for trouble checks.

An engine failure while cruising OCTA with 8,000 feet of terrain clearance also requires immediate and correct action to control the aircraft, but an initial loss of performance and altitude is not critical; there will normally be time to analyse the problem and decide whether the propeller of a failed engine must be feathered without delay.

However, if there is evidence of a serious mechanical failure or any evidence of fire, the engine must be shutdown immediately and the propeller feathered. Fortunately, these are very rare occurrences.

PHASE ONE ACTIONS

No matter what the circumstances, the Phase One actions must be performed from memory but not without thinking. Moving the wrong prop control lever to the feather position or the wrong mixture control to idle cutoff will certainly cure your asymmetric control problem, but it will do nothing for your climb performance or your image as a professional!

Similarly, applying full power on the operating engine and raising the undercarriage without thinking is definitely not the correct procedure if an engine fails at 400 feet on final approach!

REVIEW OF PHASE ONE ACTIONS

Because Phase One actions must be committed to memory, they should be kept as simple as possible, and should always be reviewed (mentally rehearsed) before starting a critical phase of flight, eg, a take-off.

PHASE TWO ACTIONS

Phase Two and subsequent actions should always be completed with reference to the procedures specified in the POH, which must be easily accessible in flight.

POST - PHASE TWO CONSIDERATIONS

If you do shut down an engine in flight, either because it has failed or as a precaution, you must contact the nearest ATC or Flight Service Unit and advise your status and intentions, but only after the aircraft is under control and all necessary actions have been completed. A Pan call is the normal means of notifying your problem.

Also, remember that if an engine fails while cruising above the single-engine Service Ceiling, you will have to descend. If this happens in Controlled Airspace, you should advise ATC of the level that you expect you will eventually be able to maintain so that any other traffic can be cleared out of your way.

Never be reluctant to speak up and ask for as much assistance as possible - asymmetric flight is definitely not “ops normal” in light twins!

Appendix 1 is an extract of CAO 20.6, which specifies the requirements.

ENGINE FAILURE DURING TAKE-OFF

DECISION POINT

As discussed in Section 2, the take-off should be based on using a decision point, rather than a decision speed, to determine the procedures to follow if an engine fails during take-off. The undercarriage is not retracted until the decision point is reached, and the physical act of moving the undercarriage lever signals the shift from one course of action to another.

In aircraft with fixed undercarriage, the decision point can be signified by changing the position of the hand on the throttles - from fingers cupped in front of the levers ready to pull back, to palm behind.

ENGINE FAILURE BEFORE DECISION POINT - BEFORE LIFTOFF

PHASE ONE ACTIONS

- MAINTAIN DIRECTION WITH RUDDERS AND CLOSE BOTH THROTTLES
- BRAKE AS NECESSARY TO STOP ON THE REMAINING RUNWAY

ENGINE FAILURE BEFORE DECISION POINT - AFTER LIFTOFF

PHASE ONE ACTIONS

- CLOSE BOTH THROTTLES AND LOWER THE NOSE
- LAND ON THE REMAINING RUNWAY
- BRAKE AS NECESSARY TO STOP OR REDUCE SPEED TO A MINIMUM BY THE END OF THE RUNWAY

ENGINE FAILURE AFTER THE DECISION POINT

PHASE ONE ACTIONS

- CONTROL - STOP THE YAW, LEVEL THE WINGS, NOSE ON THE HORIZON (+5 TO +8°) - IF NECESSARY START A GENTLE TURN TOWARDS THE “ENGINE OUT” HEADING
- POWER - BOTH THROTTLES FULLY FORWARD
- IDENTIFY - FAILED ENGINE (DEAD FOOT, DEAD ENGINE),
- CONFIRM - CLOSE THE THROTTLE OF THE FAILED ENGINE FULLY — IF NO YAW IN THE DIRECTION OF APPLIED RUDDER, VISUALLY IDENTIFY FAILED ENGINE PROP LEVER, USING THE CLOSED THROTTLE AS A “FLAG”,
- FEATHER
- CHECK FOR FIRE - IF FIRE IS EVIDENT OR SUSPECTED, IDENTIFY THE FAILED ENGINE MIXTURE CONTROL AND CLOSE, THEN POSITIVELY IDENTIFY THE FAILED ENGINE FUEL SELECTOR AND MOVE TO “OFF”
- BANK AND BALANCE
- IF CLIMB PERFORMANCE IS CRITICAL, BANK THREE DEGREES TOWARDS THE OPERATING ENGINE AND USE RUDDER TO MAINTAIN DIRECTION (BALANCE BALL ONE TO ONE HALF BALL-WIDTH TOWARDS THE OPERATING ENGINE)
- FLAPS - COWL FLAPS CLOSED, WING FLAPS RETRACTED
- TRIMS - AS REQUIRED TO RELIEVE CONTROL LOADS.

PHASE TWO ACTIONS

Mixture Control and Magneto Switches

Logically, the failed engine mixture control need not be closed unless there is an engine fire. Once the propeller has feathered and the engine has stopped, moving the failed engine mixture control to idle cutoff has no effect, but moving the wrong lever certainly has! The same applies to magneto switches - if the engine is not rotating, the position of the magneto switches is irrelevant.

ENGINE FAILURE IN THE CLIMB AND CRUISE

PHASE ONE ACTIONS

- CONTROL - STOP THE YAW, LEVEL THE WINGS, PITCH ATTITUDE TO MAINTAIN DESIRED FLIGHT PATH AND a MINIMUM OF Vyse
- POWER - MIXTURE, PITCH AND THROTTLES FORWARD
- IDENTIFY - FAILED ENGINE (DEAD FOOT, DEAD ENGINE)
- CONFIRM - FULLY CLOSE THE THROTTLE OF THE FAILED ENGINE
- TRIM

PHASE TWO ACTIONS

Refer to the POH, but remember that, apart from the mechanical components (which rarely fail), an engine only needs fuel, air and ignition to operate. The symptoms of an engine failure, whether partial or complete, will often help to identify the cause and possible corrective action.

DIAGNOSIS OF ENGINE FAILURE

Fuel Starvation / Contamination

If the engine has quietly "died" or loses power after some surging, the problem is probably fuel starvation or fuel contamination, and possibly may be cured by turning on the electric auxiliary fuel pump (if applicable), selecting another tank, and/or selecting crossfeed on.

If your initial multi-engine training has been done properly, you should recognize these symptoms, because your instructor should have initiated an engine failure by turning off the fuel at least once for a realistic simulation of fuel starvation, rather than always using the unrealistic, but more convenient, closing of the throttle or mixture controls.

Rough Running

If the engine is running roughly (possibly accompanied by misfiring) the problem may be caused by fuel contamination, a "breathing" problem, an internal magneto problem, or a mechanical problem such as a stuck valve or possibly a blocked injector in a fuel-injected engine. In this case:

a. Complete the fuel starvation/contamination checks

b. If these do not cure the problem, select carburettor heat on or, with fuel injected engines, select alternate air to bypass the air filter. If the engine then responds normally to throttle movement the problem is a blocked air inlet (ice?)

c. If neither the fuel system or air supply checks are effective, select each magneto off then on in turn - if the engine runs more smoothly on one magneto but not on both, continue the flight on the good magneto but land at the nearest suitable airfield where the problem can be rectified.

d. If none of the fuel, air or ignition checks isolate the problem but the engine continues to run roughly without any loud mechanical noises, one cylinder is probably not functioning due to a stuck valve or (if applicable) a blocked injector. Continued operation of the engine will probably not do any further damage, but if in doubt and the power from the rough running engine is not essential, carefully identify the correct levers, close the mixture control and feather the propeller. If you do continue to operate a rough-running engine because you need the power to maintain altitude until you clear high terrain, closely monitor all the engine indications and be prepared to shut the engine down and feather the propeller at the first signs of loss of oil pressure or excessive temperatures.

ENGINE FAILURE IN THE DESCENT

GENERAL CONSIDERATIONS

An engine failure in a descent at reduced power is normally not as critical as in other stages of flight - the reduced power will produce less yaw, and performance will not normally be of major concern.

The normal control movements will still be required to maintain the aircraft’s desired flight path, but they will be of a lesser magnitude. Cruise power on the operating engine should be sufficient to maintain “Blue Line” speed or higher, even with undercarriage extended.

Therefore, there is normally no requirement to raise undercarriage or flaps immediately. When leveling on completion of an asymmetric descent, extended undercarriage and/or flaps will only need to be retracted if the power available is insufficient to maintain Vyse.

If “Blue Line” speed cannot be maintained, then the aircraft certainly should be “cleaned up”, but don’t forget to extend the undercarriage again for landing.

PHASE ONE ACTIONS

- CONTROL - RUDDER TO STOP THE YAW, PITCH ATTITUDE AND BANK TO MAINTAIN THE DESIRED FLIGHT PATH
- POWER - THROTTLES TO CRUISE POWER
- IDENTIFY - THE FAILED ENGINE (DEAD FOOT, DEAD ENGINE)
- CONFIRM - BY FULLY CLOSING THE FAILED ENGINE THROTTLE
- TRIM

PHASE TWO ACTIONS

Instrument Approach Considerations

During an instrument approach the cockpit workload is high and the priority requirement is to maintain the flight path accurately to ensure terrain clearance. If an engine failure occurs in these circumstances, you probably cannot afford to have your attention diverted to conduct trouble checks as you would in the climb, cruise or visual descent.

If an engine fails during an instrument approach the recommended procedure is to conduct the normal Phase One checks including identification, confirmation and feathering. If the undercarriage has been extended, don't automatically retract it unless you cannot maintain “Blue Line” speed using available power. Also, don't use more than one stage of flap until you become visual.

You will probably become visual at or before the Minimum Descent Altitude or Decision Height for the approach, and complete an asymmetric landing. If you don't become visual before the Missed Approach Point, apply full power on the operating engine, select 8 degrees nose up on the Attitude Indicator and retract the undercarriage and flaps (if extended) and follow the Missed Approach procedure.

If you have to divert to another airfield, consider your ability to maintain LSA on one engine. If in a radar environment, request headings to maintain the greatest terrain clearance, and any other help possible.

If there is a possibility that you may not become visual at the MDA at your planned destination, consider a diversion before you begin an instrument approach. The diversion should be to a field with an approach to the lowest minimum; preferably an ILS.

ASYMMETRIC CIRCUIT PROCEDURES

If you are joining the circuit with an engine shut down, plan a normal approach. If full power on the operating engine does not provide a speed of about 10 -15 knots above “Blue Line” on downwind, delay the gear extension until turning base.

APPROACH POWER REQUIREMENTS AND CONFIGURATION

From the base turn point, you will probably only need about 3 - 5" more Manifold Pressure than for a normal two-engine approach. Maintain a minimum of Target Threshold Speed (TTS) + 10 kts until committal height of about 300 feet AGL. Unless you are landing on a minimum length runway, don’t use full flap for landing - you really don’t need the extra drag!

However, if you do use full flap don’t select it until you are committed to the landing. Above all, don’t get low on finals - make a normal or slightly higher approach, reducing to normal approach speed after you have committed yourself to land.

SINGLE ENGINE MISSED APPROACH

If you have to execute a single-engine missed approach, do so before you reach Committal Height. Apply full power on the operating engine while stopping the yaw with rudder. Raise the nose to a shallow climb attitude. Select gear up, then retract the flaps - in stages if you have unwisely lowered full flap early! As the gear and flaps retract, maintain about an 8° nose up attitude, and climb away for a rejoin.

ENGINE FAILURE ON FINAL APPROACH

If you are unlucky enough to lose an engine on finals, don’t unthinkingly go into the routine of “full power, gear and flaps up” and start a missed approach! Simply stop the yaw (which will probably be very little), advance the power as needed to maintain approach speed, and continue with the landing.

On a normal approach profile at normal approach speed, the drag from a windmilling prop should not cause a dangerous loss of speed provided the throttles are opened to increase the power from the operating engine.

However, if you have been unwise enough to make a “submarine” approach (which is a “no-no” in twins), you may need to identify, confirm and feather quickly to prevent the speed falling rapidly towards Vmc. The alternative is to land short of the runway.

USE OF TRIMS AND AUTOPILOT

Use of Trims

Once you have the aircraft under control and performing as well as circumstances allow, use the rudder trim to remove, or at least reduce, the foot loads. Holding lots of rudder by foot pressure alone can start “knee shaking” fairly quickly.

Use of the Autopilot

If the engine fails in the cruise or descent, consider using the autopilot (if fitted and approved for asymmetric flight) after you have manually trimmed the aircraft. Use of the autopilot will allow you to concentrate more on the management of the flight and your options, rather than having to give most of your concentration to hand-flying.

Many auto-pilots will automatically apply about 5 degrees of bank towards the live engine to maintain a selected heading if the rudder has been trimmed to hold about one ball displacement towards the operating engine.

Don’t engage “altitude hold” unless you are at or below the single-engine service ceiling, and even then monitor the speed carefully. An autopilot is not normally programmed to maintain a minimum speed, and in the altitude hold mode it will probably raise the nose as much as it can to maintain altitude!

APPENDIX 1

EXTRACT FROM CIVIL AVIATION ORDER 20.6

“3.1 When an engine of an aircraft fails in flight or where the rotation of an engine of an aircraft is stopped in flight as a precautionary measure to prevent possible damage, the pilot-in-command shall notify the nearest Air Traffic Control or Communications Unit immediately, giving all relevant information and stating the action he (she) intends to take in regard to the conduct of the flight.

3.2 The pilot-in command of a multi-engine aircraft in which one engine or the rotation thereof is stopped may proceed to an aerodrome of his (her) selection instead of the nearest suitable aerodrome if, upon consideration of all relevant factors, he (she) deems such action to be safe and operationally acceptable. These factors shall include the following:

(a) nature of the malfunctioning and the possible mechanical difficulties which may be encountered if flight is continued;

(b) availability of the inoperative engine for use;

(c) altitude, aircraft weight, and usable fuel at the time of engine stoppage;

(d) distance to be flown coupled with the performance availability should another engine fail

(e) relative characteristics of the aerodromes available for landing;

(f) weather conditions enroute and at possible landing points

(g) air traffic congestion;

(h) type of terrain; and

(i) familiarity of the pilot with the aerodrome to be used.”

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SECTION 4

FLIGHT PLANNING AND PERFORMANCE

MULTI-ENGINE FLIGHT MANUAL FOR PROFESSIONAL PILOTS

SECTION 4 – FLIGHT PLANNING AND PERFORMANCE

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FLIGHT PLANNING

Multi-engine flight planning is normally more time consuming than for a "single" and requires extra care and thought because of:

a. the normally more complex weight and balance calculations,

b. the need to determine whether climb performance following an engine failure after take-off will provide terrain clearance while manoeuvring for an asymmetric landing, and

c. the need to determine whether you will be able to maintain terrain clearance if an engine fails during the cruise.

Although VFR flights do not require submission of flight details to ATC, this should never be an excuse for not fully and carefully planning every flight.

FLIGHT PLANNING AIDS

Although multi-engine flight planning is more complex than for a single-engine aircraft, it can be streamlined by using a number of aids. The Appendices to this Section include a number of charts which can be used to simplify flight planning calculations for any aircraft.

You can also prepare other planning aids for the aircraft which you fly regularly. This Section contains a number of suggestions and examples, based on a typical light twin.

A blank Flight Data Card, the format of which is used throughout this Section, is included as Appendix 1 for photocopying. The use of these cards in flight planning is highly recommended.

There are a number of excellent computer flight planning programs available for the Australian environment. Most of the increasingly popular GPS sets have the facility to store and recall standard flight plans. However, remember the old programmer's saying - "garbage in, garbage out" - and take extra care if entering data (particularly aircraft performance data and waypoint lat/long) into a computer flight planning program, or into a GPS set.

FLIGHT PLANNING CHECKLISTS

No matter what your level of experience, the use of some form of flight planning checklist is professional, particularly if you don't fly regularly. It will probably save you time and help to ensure that nothing important is forgotten.

Included are examples of VFR and IFR Flight Data Cards which you can copy and which record information needed to assist safe multi-engine operations.

Completion of Flight Data Cards such as these serves the purpose of a flight planning checklist, and is strongly recommended to assist flight planning and reduce cockpit workload.

RELATIONSHIP BETWEEN INDICATED ALTITUDE, PRESSURE ALTITUDE AND DENSITY ALTITUDE

Throughout this Section, we will be using the terms Indicated Altitude, Pressure Altitude and Density Altitude.

By way of revision, and hopefully to avoid any confusion, these terms will be defined and explained.

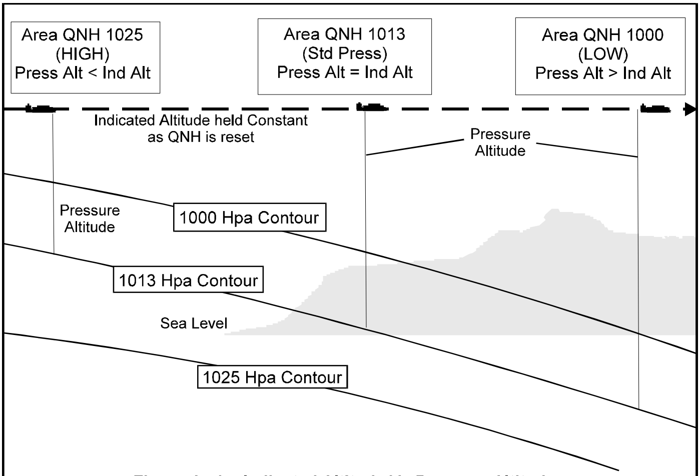


Figure 4 - 1. Indicated Altitude Vs Pressure Altitude

Indicated Altitude

Indicated Altitude is the height of the aircraft above the local Sea Level pressure (QNH). Provided the QNH has been set accurately on the altimeter sub-scale and the QNH is the actual sea level pressure below the aircraft's position, the Indicated Altitude will be the aircraft's actual altitude above sea level.

Pressure Altitude

Pressure Altitude is the height of the aircraft above the standard 1013 Hpa pressure level. If the QNH (sea level pressure) is 1013 Hpa, Pressure Altitude is the same as Indicated Altitude.

If the QNH is less than 1013 Hpa, the aircraft's Indicated Altitude will be less than the Pressure Altitude.

Density Altitude

Any decrease in air density will reduce the power output of an un-supercharged piston engine, and will therefore have a detrimental effect on aircraft performance.

Air density decreases as Pressure Altitude increases because of the natural reduction in air pressure.

However, air density also decreases considerably with increases in temperature even though the Pressure Altitude remains unchanged.

Predicted aircraft performance data is based on the use of standard pressures and temperatures in the International Standard Atmosphere - the "ISA". Among other things, the ISA assumes a Sea Level temperature of 15 º C, which reduces by 1.98 º C for each 1,000 feet increase in altitude.

If an aircraft is flying at an altitude where the temperature is different from the ISA temperature, the air density will not be the same as it would be in the ISA. Therefore, the performance would be that which could be expected at the ISA altitude with the equivalent air density.

This equivalent ISA altitude is called the "Density Altitude". Density Altitude varies from Pressure Altitude by 120 feet for each 1 º difference between actual and ISA temperatures. Higher temperatures mean higher Density Altitudes.

For example, assume that an aircraft is flying at 5,000 feet Pressure Altitude with an Outside Air Temperature (OAT) of 15 degrees. This temperature is 10 degrees higher than ISA, and the equivalent Density Altitude is 6,200 feet; 5,000 + (10 x 120). Therefore, the aircraft would perform as it would at 6,200 feet in the ISA.

If aircraft performance data in the POH is presented in graphical format, the Pressure Altitude - Air Temperature grid normally has a reference line showing temperatures in the ISA.

Density Altitude is particularly important when considering single-engine climb performance.

MAXIMUM TAKE-OFF WEIGHT FOR SAFE SINGLE-ENGINE CLIMB PERFORMANCE

Casa Single-Engine Performance Requirements

The CASA specifies minimum single-engine climb performance requirements for both initial aircraft certification and for actual operations. These requirements are shown in Appendix 2.

Certification Requirements

Based on the CASA Certification requirements, an Australian registered multi-engine aircraft must be able to maintain level flight at 5,000 feet Pressure Altitude at a temperature of ISA + 10º (6,200 feet Density Altitude) following the failure of an engine, under the following conditions:

a. maximum take-off weight;

b. airspeed not less than 1.2 Vs1;

c. critical engine inoperative and it's propeller feathered; and

d. remaining engine(s) operating at maximum continuous power.

In addition, a weight not greater than the maximum allowable take-off weight shall be determined that will enable a 0.5% climb gradient at 6,200 feet Density Altitude under the conditions specified above.

Operational Requirements

The operational application of these certifications criteria is that aircraft engaged in IFR charter or aerial work (including training) operations must be able to maintain a 1% climb gradient up to 5,000 feet density altitude, in a clean configuration and with the propeller of the inoperative engine feathered.

For all other operations, ie, private or VFR charter, the aircraft must be able to maintain level flight up to 5,000 feet density altitude, clean and with the inoperative engine's propeller feathered.

Compliance with these requirements may require the take-off weight to be reduced below the maximum allowable.

Density Altitude Vs Indicated Altitude Considerations

The Density Altitude specified in the CASA performance requirements may equate to a much lower Indicated altitude in the Australian summer.

This possible difference should always be considered as part of your pre-flight planning, because of the effect it may have on asymmetric climb performance immediately after take-off.

Calculation of Minimum Fuel Required

As discussed in Section 3, weight variations have a significant effect on single-engine climb performance, which must be a major consideration in multi-engine flight planning. It is, after all, one of the main reasons for operating a twin rather a single.

Other than the weight of passengers and baggage, fuel weight is the only variable over which the pilot has control.

Therefore, we recommend that the first step in multi-engine flight planning should be to determine the minimum fuel required for each stage of a planned flight.

CALCULATION OF FUEL REQUIRED

The initial calculation of minimum fuel can be streamlined by constructing a graph from which the fuel required can be determined for a range of flight distances and ground speeds, or maximum flight distance can be determined given a probable ground speed and maximum fuel available..

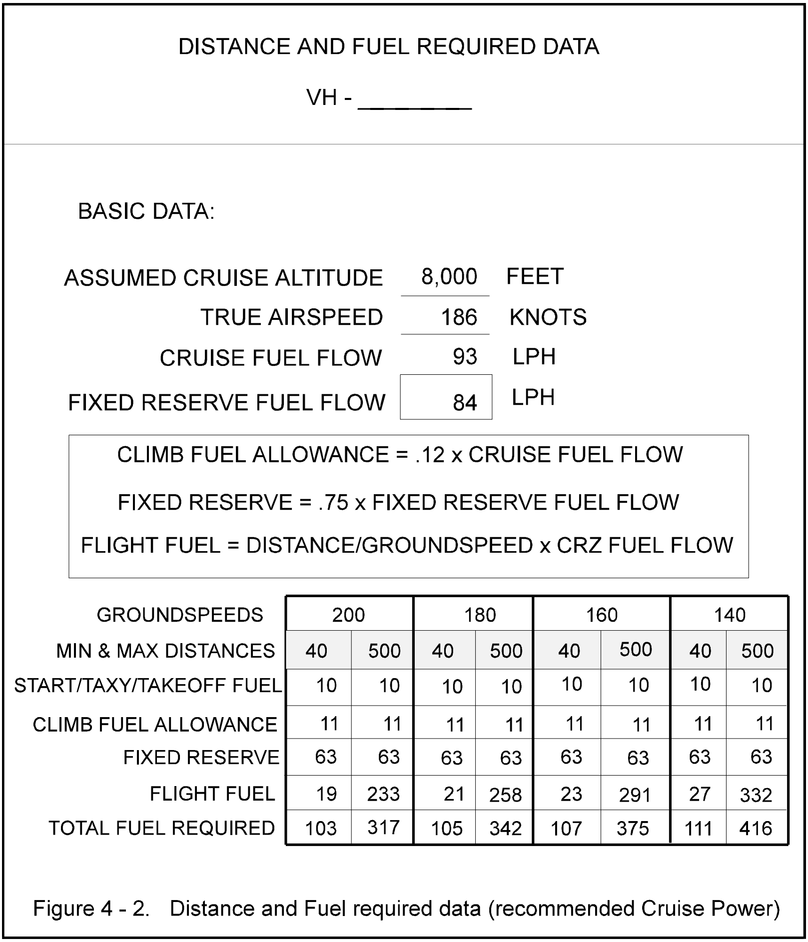
To simplify construction and to help avoid interpretation errors, separate graphs should be constructed for VFR and IFR operations.

The following describes the construction of a VFR graph; the construction of an IFR graph is essentially identical, except that a 15% increase in planned cruise fuel flow is recommended for IFR flights to provide for an additional Variable Reserve.

To construct the graph we first complete a table which contains the basic data which is calculated from information in the POH.

Appendix 3 is a blank form which can be used to build the table for the aircraft which you fly. Figure 4 - 2 is a completed table for a typical light twin - a Beech Baron B58, and this typical aircraft will be used as an example for the remainder of this Section.

Only minimum and maximum flight distances need to be used in the calculations, as the groundspeed lines on the completed graph are straight lines, and only two data points are needed to draw these lines.



DISTANCE AND FUEL REQUIRED DATA

VH - ________

BASIC DATA:

ASSUMED CRUISE ALTITUDE 8,000 FEET
TRUE AIRSPEED 186 KNOTS
CRUISE FUEL FLOW 93 LPH
FIXED RESERVE FUEL FLOW 84 LPH

CLIMB FUEL ALLOWANCE = .12 x CRUISE FUEL FLOW
FIXED RESERVE = .75 x FIXED RESERVE FUEL FLOW
FLIGHT FUEL = DISTANCE/GROUNDSPEED x CRZ FUEL FLOW

GROUNDSPEEDS	200		180		160		140	
MIN & MAX DISTANCES	40	500	40	500	40	500	40	500
START/TAXY/TAKEOFF FUEL	10	10	10	10	10	10	10	10
CLIMB FUEL ALLOWANCE	11	11	11	11	11	11	11	11
FIXED RESERVE	63	63	63	63	63	63	63	63
FLIGHT FUEL	19	233	21	258	23	291	27	332
TOTAL FUEL REQUIRED	103	317	105	342	107	375	111	416

Figure 4 - 2. Distance and Fuel required data (recommended Cruise Power)

The minimum flight distance of 40 nms represents the shortest flight which would probably be conducted in practice.

We have used a maximum flight distance of 500 nms because although the aircraft may be able to fly further with full fuel, you and/or your passengers would probably need a "comfort stop" after flying this distance!

PLANNING ASSUMPTIONS

We recommend you use:

a. an assumed cruising altitude of, say, 8,000 feet; and

b. the TAS and fuel flow, as shown in the POH, applicable to your normal cruise power setting and this altitude

The example table in Figure 4 - 2 is based on our typical light twin using the manufacturer's recommended cruise power setting, giving a TAS of 186 kts at 8,000 feet and a fuel flow of 93 litres per hour.

For other power settings we would construct separate tables.

Range of Ground Speeds

The Fuel Required table is subdivided into four columns for a range of ground speeds.

In our example (Figure 4 - 2), we have assumed ground speeds of 140, 160, 180 and 200 knots. These approximate a reasonable range of ground speeds for the Baron.

Fuel Required Data

Our calculations of the fuel required must include allowances for the fuel used during start, taxi and take-off, the extra fuel used during the climb, and a Fixed Reserve

Start, Taxi and Take-off Fuel Allowance.

The manufacturer may recommend an allowance for start, taxi and take-off fuel, usually in the Climb Time, Distance and Fuel Used chart in the POH. In the case of our example, the recommendation is 10 litres, and this will be added to the fuel required figures which we now determine

Climb Fuel.

Climb Fuel is the extra fuel you would consume in a climb in addition to the fuel which would be used if you were operating at normal cruise power during the time spent in the climb.

As a reasonable rule-of-thumb, you can assume the extra fuel to be 1.5% of your cruise fuel flow for each 1,000 feet in the climb.

In our example, this is 12% (1.5% x 8) - giving an extra climb fuel of 11 litres (0.12 x 93).

Fixed Reserve

Although there is no longer any mandatory fuel reserve specified by the CASA, we recommend a 45 minute fixed reserve calculated at the manufacturer's endurance power setting

In the Baron, the recommended Endurance power setting gives a fuel flow of 84 litres per hour. This gives a Fixed Reserve of 63 litres - (0.75 x 84).

Flight Fuel

Flight Fuel is the fuel we expect to use during the cruise over the total flight distance.

It is determined by dividing the flight distance by the groundspeed and multiplying the result by the cruise fuel flow.

The resulting figures for our example twin are shown in Figure 4 - 2, and these are the data points for our groundspeed lines in the completed graph - Figure 4 - 3.

Holding Fuel

Holding Fuel may be required for VFR or IFR operations.

Major airfields may require the provision of Holding Fuel for VFR operations because of traffic density during certain hours of the day. These requirements are specified in AIPs.

Although holding fuel requirements cannot be included in the construction of the graph, any holding fuel required can be included in the Flight Data Card, as shown later in this Section.

The quantity of fuel required for holding should be based on a reduced fuel flow: We recommend the same fuel flow as used for the Fixed Reserve.

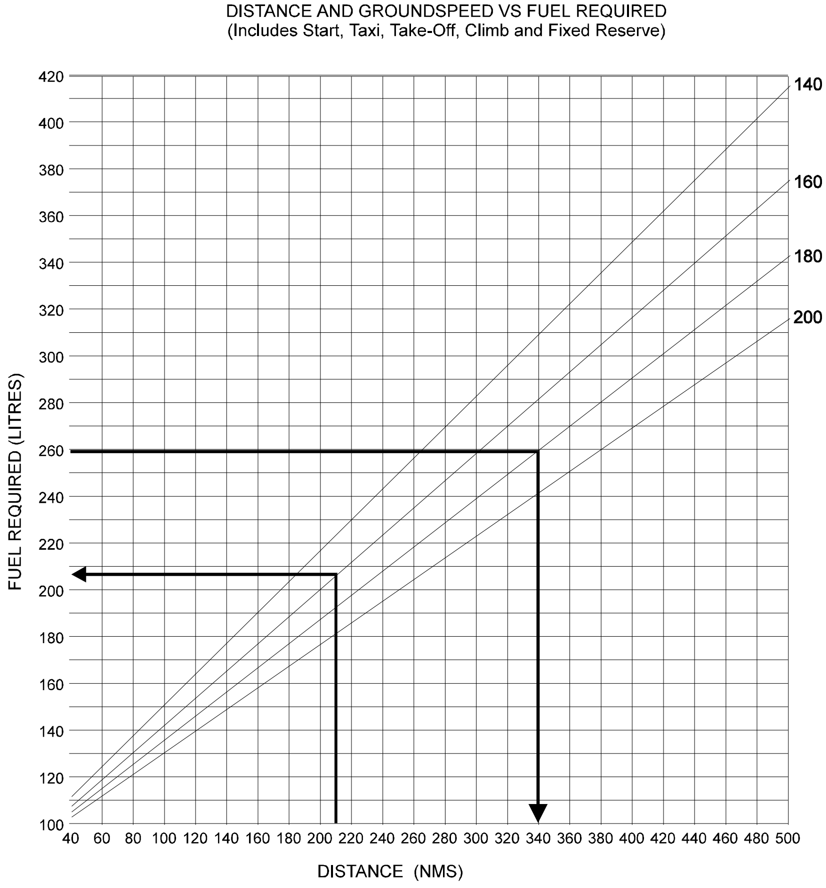


Figure 4 - 3. Fuel Required Vs Flight Distance and Groundspeed

DISTANCE/FUEL REQUIRED GRAPH CONSTRUCTION

A sample Distance/Fuel Required graph is shown in Figure 4 - 3.

First, draw a horizontal (bottom) axis to cover the flight distances from 40 to 500 nms, with each vertical grid line representing, say, 20 nms.

Groundspeed Line Construction

Draw a vertical (left) axis upward from the left end of the distance scale, with each grid line equal to 10 litres and the scale covering the range of fuel required from the minimum to the maximum.

In the example table in Figure 4 - 2, the minimum fuel required is 103 litres (40 Nms @ 200 Kts) and the maximum fuel required is 416 litres (500 Nms @ 140 Kts). The Fuel Required/Available scale therefore extends from 100 to 420 litres to cover this range.

On the graph, plot the points for the minimum fuel quantities for each groundspeed on the left hand axis. Then plot the maximum fuel quantities for each ground speed on the 500 nms grid line. Join each pair of points with a straight line to produce groundspeed lines covering the distance scale, as shown in Figure 4 - 3.

Ground speeds within the maximum and minimum plotted can be interpolated with acceptable accuracy.

The arrowed lines in Figure 4 - 3 show an example of how this graph can be used. Assuming a distance of 210 nms and a groundspeed of 160 kts, we would require a minimum fuel of 208 litres.

On the other hand, a useable fuel quantity of 260 litres at start with a forecast ground speed of 180 kts would be adequate for a flight distance of 340 Nms.

Fuel Quantity to Fuel Weight

For later planning steps, we need to know the weight of the fuel required, as well as the quantity.

To convert litres to kilograms, multiply the quantity figure by .72 - the Specific Gravity of AVGAS.

However, in the next flight planning step we describe the construction of another graph from which fuel weight can be read directly.

Initial Calculation of TOW

For any flight, you need to determine either:

a. the maximum payload (passenger and baggage weight) you can carry after determining the minimum fuel required for the planned flight distance: or

b. given an intended payload, the maximum weight/quantity of fuel you can carry

without exceeding the maximum TOW limit for your aircraft.

This can be done as part of a normal weight and balance calculation. However, you can again construct a graph which will simplify the process, as a companion to the Distance/Fuel Required graph.

Payload Available and Fuel Weight Graph

Although construction of this graph is relatively simple, the following example uses data for our typical twin (Baron B58) to assist the explanation, and assumes:

a. a Basic Weight of 1595 kgs,

b. a Maximum TOW of 2450 kgs, and

c. a weight of pilot plus equipment and baggage of 90 kgs.

Appendix 4 is a form which can be used to record the data needed to construct the Payload Available/Fuel Weight Graph.

Figure 4 - 4 is an example of the table completed for our typical twin.

PAYLOAD AVAILABLE AND FUEL WEIGHT TABLE

VH - ________

MAX/MIN WEIGHTS (KGS) AND FUEL QUANTITIES (LTS)

	MAXIMUM TOW	2450	From POH
	BASIC WEIGHT	1595	From POH (Basic Weight plus oil)
	PILOT PLUS EQUIPMENT	90	
	OPERATING WEIGHT	1685	Basic Weight plus pilot
1	USEFUL LOAD	765	Max TOW - Operating Weight

FUEL REQUIRED FOR MAXIMUM AND MINIMUM DISTANCES

2	MINIMUM FUEL REQUIRED	103	Graph Points A and C
3	MAXIMUM FUEL REQUIRED	416	Graph Points B and D

MAXIMUM AND MINIMUM WEIGHTS

4	**MIN FUEL WEIGHT (LINE 2 x .72)**	74	Graph Point C
5	**MAX FUEL WEIGHT (LINE 3 x .72)**	300	Graph Point D
6	**MAX PAYLOAD (LINE 1 - LINE 4)**	691	Graph Point A
7	**MIN PAYLOAD (LINE 1 - LINE 5)**	465	Graph Point B

Figure 4 - 4. Payload Available and Fuel Weight Table

To complete the form at Appendix 4:

a. Add your own weight plus that of your normal equipment and baggage to the basic weight of the aircraft, which is specified in the Loading Data Section of the AFM. The resulting figure is the aircraft Operating Weight (Basic Weight + pilot, pilot's equipment and baggage). In our example, the Operating Weight is 1685 kgs (1595 + 90).

b. Subtract this Operating Weight from the Maximum Take-off Weight specified in the Limitations Section of the AFM to determine the Useful Load (passengers + baggage + fuel). In our example, the useful load is 765 kgs (2450 - 1685).

c. From your Distance/Fuel Required table, eg, Figure 4 - 2, determine the minimum fuel required at the highest ground speed and the maximum fuel required at the slowest ground speed. In our example, these figures are 103 litres and 416 litres

d. Convert these quantities to weight in kilograms by multiplying by 0.72 (the standard AVGAS conversion). In our example, the figures are:

(i)	minimum fuel weight	74 kgs (103 x 0.72)
(ii)	maximum fuel weight	300 kgs (416 x 0.72)

e. Subtract these minimum and maximum fuel weights from the Useful Loads found in step b. to determine the range of Payload (passenger/baggage) weights available. In our example, the resulting figures are:

(i)	maximum Payload	691 kgs (765 - 74), and
(ii)	minimum Payload	465 kgs (765 - 300)

We can now use the data in the table (Figure 4 - 4) to construct a graph. Figure 4 - 5 is an example for our typical twin.

a. Draw a bottom (horizontal) axis covering the minimum to maximum fuel quantities required in 20 litre steps. In our example (Figure 4 - 5) the range is from 100 to 420 litres.

b. Draw a left-hand (vertical) axis to cover the range from the minimum fuel weight to the maximum payload weight. In Figure 4 - 5, this axis covers the range 0 to 800 kgs in 20 kg steps.

c. Plot the points which correspond to the minimum fuel quantity and maximum payload - in our example 103 litres and 691 kgs (Point A) - and the maximum fuel quantity and minimum payload — in our example 416 litres/465 kgs (Point B). Join these two points by a straight line over the width of the graph.

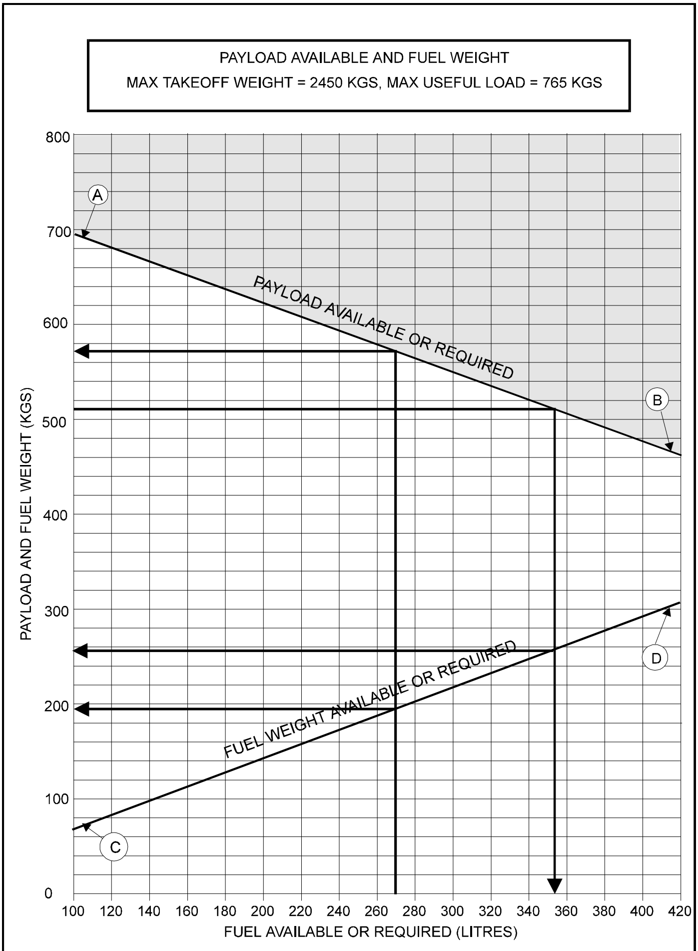


Figure 4 - 5. Fuel and Payload Weight Available or Required

d. Plot the points for the minimum and maximum fuel quantities and their corresponding weights — in our example, 103 litres and 74 kgs (Point C) and 416 litres and 300 kgs (Point D). Join these points with a straight line extending over the width of the graph.

The completed graph can now be used to find:

a. the available payload weight for any minimum fuel quantity required for a particular flight, and the weight of that fuel;

b. the maximum fuel weight (and quantity) which can be carried with a known payload weight.

As examples, Figure 4 - 5 shows that with a required fuel quantity of 270 litres to cover a particular flight distance, a maximum payload of 572 kgs is available and the fuel weight is 195 kgs. Conversely, if a payload of 510 kgs is to be carried, the maximum fuel weight available is 256 kgs - a quantity of 355 litres.

Standard Passenger Weights

If we were to use the old system of "standard" 77 kg passengers, we could quickly convert a Payload Available to a possible number of passengers and baggage weight.

However, the CASA advises in Civil Aviation Advisory Publication (CAAP) 235 - 1 that standard passenger weights not be used in aircraft with less than 9 seats, as there is a high probability of overloading.

In light twin flight planning, actual passengers and baggage weights should be used to determine that a planned payload is not greater than the maximum available.

Adjustment of Fuel and/or Payload

If your planned payload is greater than the payload available, you have two options:

a. Reduce the weight of passengers and/or baggage, or

b. Reduce the fuel weight

If you decide to reduce the minimum fuel weight, you will naturally have to plan a shorter flight distance between refueling stops.

Zero Fuel Weight

In addition to maximum TOW, your AFM may also specify a maximum Zero Fuel Weight (ZFW).

The weight of fuel in the wings of an aircraft in flight actually reduces the bending loads which are applied where the wing spars are attached to the fuselage. Therefore, these loads are greatest when the fuel tanks are empty and the aircraft weight is concentrated in the fuselage.

A maximum ZFW (if specified) is the maximum weight allowable before any fuel is added. To determine a ZFW, simply add your planned payload to your Operating Weight, and check that this does not exceed the maximum ZFW. If it does, some of your payload will have to find another means of transport!

INITIAL USE OF THE FLIGHT DATA CARD

This is the time to start filling in the Flight Data Card (FDC).

Figure 4 - 6 is a sample FDC for an IFR flight in the twin used as an example so far in this Section.

Initial flight planning data is:

a. a planned flight distance of 245 nms (Line 1),

b. an expected ground speed of 160 kts (Line 2),

c. a requirement for 15 mins traffic holding at the destination airfield, which means we must carry an additional 21 litres (.25 x 84 - Line 4).

d. Operating Weight of 1685 kgs (Line 9)

From Figure 4 - 3, the minimum fuel required for 245 nms is 226 litres. This is entered in the FDC at Line 3.

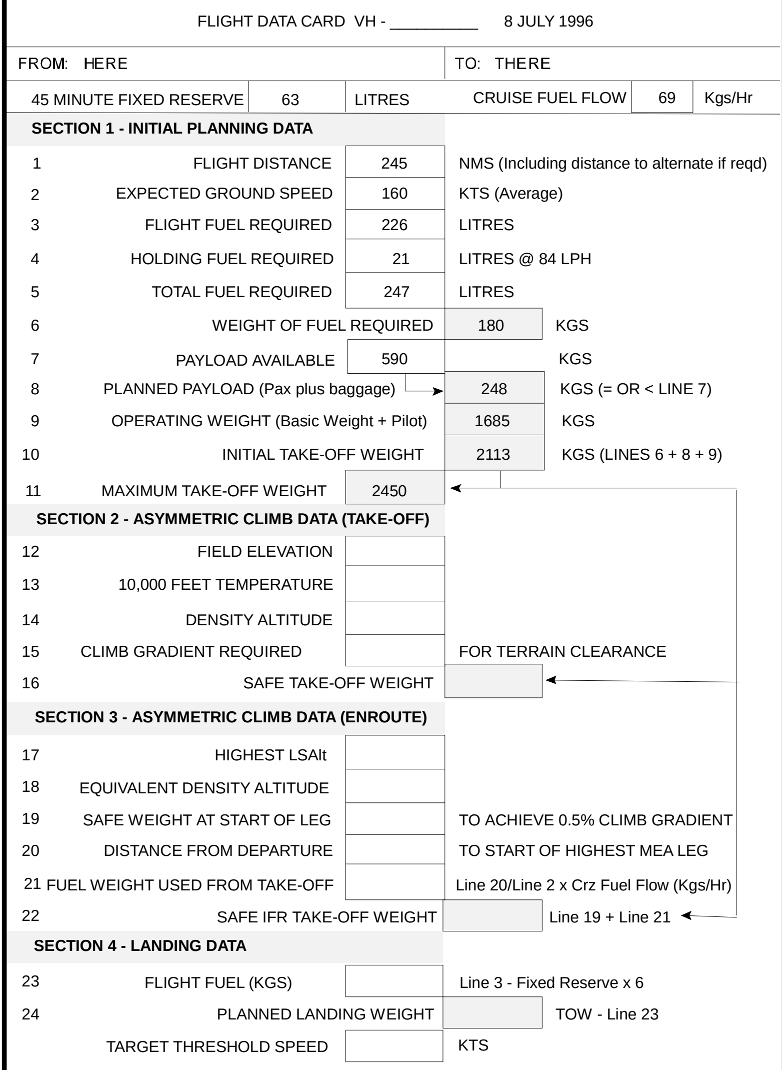
This fuel required is added to the holding fuel (Line 4) to give a total minimum fuel requirement of 247 litres (Line 5)

From Figure 4 - 5, the 247 litres of fuel has a weight of 180 kgs and the Payload available is 590 kgs. These figures are entered in the FDC at Lines 6 and 7.

The planned payload consists of three passengers with a combined weight of 225 kgs and 23 kgs of baggage - a total planned payload weight of 248 kgs, which is entered at Line 8.

Adding the Fuel Weight (Line 6) to the Planned Payload (Line 8) and the Operating Weight (Line 9), the initial TOW is 2113 kgs (FDC Line 10), which is well below the maximum allowable TOW of 2450 kgs (Line 11)

However, we now need to determine whether this initial TOW, which seems well within limits, will enable an acceptable climb performance in the event of an engine failure.



FLIGHT DATA CARD VH - __________ 8 JULY 1996

FROM: HERE | TO: THERE

45 MINUTE FIXED RESERVE 63 LITRES | CRUISE FUEL FLOW 69 Kgs/Hr

SECTION 1 - INITIAL PLANNING DATA			
1	FLIGHT DISTANCE	245	NMS (Including distance to alternate if reqd)
2	EXPECTED GROUND SPEED	160	KTS (Average)
3	FLIGHT FUEL REQUIRED	226	LITRES
4	HOLDING FUEL REQUIRED	21	LITRES @ 84 LPH
5	TOTAL FUEL REQUIRED	247	LITRES
6	WEIGHT OF FUEL REQUIRED	180	KGS
7	PAYLOAD AVAILABLE	590	KGS
8	PLANNED PAYLOAD (Pax plus baggage)	248	KGS (= OR < LINE 7)
9	OPERATING WEIGHT (Basic Weight + Pilot)	1685	KGS
10	INITIAL TAKE-OFF WEIGHT	2113	KGS (LINES 6 + 8 + 9)
11	MAXIMUM TAKE-OFF WEIGHT	2450	
SECTION 2 - ASYMMETRIC CLIMB DATA (TAKE-OFF)			
12	FIELD ELEVATION		
13	10,000 FEET TEMPERATURE		
14	DENSITY ALTITUDE		
15	CLIMB GRADIENT REQUIRED		FOR TERRAIN CLEARANCE
16	SAFE TAKE-OFF WEIGHT		
SECTION 3 - ASYMMETRIC CLIMB DATA (ENROUTE)			
17	HIGHEST LSAlt		
18	EQUIVALENT DENSITY ALTITUDE		
19	SAFE WEIGHT AT START OF LEG		TO ACHIEVE 0.5% CLIMB GRADIENT
20	DISTANCE FROM DEPARTURE		TO START OF HIGHEST MEA LEG
21	FUEL WEIGHT USED FROM TAKE-OFF		Line 20/Line 2 x Crz Fuel Flow (Kgs/Hr)
22	SAFE IFR TAKE-OFF WEIGHT		Line 19 + Line 21
SECTION 4 - LANDING DATA			
23	FLIGHT FUEL (KGS)		Line 3 - Fixed Reserve x 6
24	PLANNED LANDING WEIGHT		TOW - Line 23
	TARGET THRESHOLD SPEED		KTS

Figure 4 - 6 Flight Data Card with Section 1 Completed

ASYMMETRIC CLIMB PERFORMANCE AFTER TAKE-OFF

Climb Gradient Required

The asymmetric climb performance (climb gradient) actually available depends on:

a. the density altitude (DA) at the departure field, and

b. the take-off weight.

VFR

The minimum asymmetric climb performance required after take-off will depend on the terrain in the vicinity of the departure airfield. A 3% climb gradient in VMC should ensure terrain clearance during the initial climb, as this is the maximum obstacle clearance gradient recommended for an ALA.

In a typical light twin, between approximately 200 and 300 feet per minute rate of climb will be needed to give a 3% climb gradient, dependent on Vyse and headwind component along your flight path.

IFR

For IFR operations, the climb gradient needed to meet Standard Instrument Departure (SID) terrain clearance requirements may be as high as 4%. If climb gradients of this order are needed, you will need to consider before take-off how you will manoeuvre to maintain terrain clearance if an engine fails after take-off in IMC.

CONVERSION OF FIELD ELEVATION TO DENSITY ALTITUDE

The first step in determining probable asymmetric climb gradient after take-off is to convert field elevation to an equivalent DA. The first step is normally to convert Field Elevation to a Pressure Altitude.

CALCULATION OF PRESSURE ALTITUDE

If you are planning while close to your aircraft at the departure field, you can set the altimeter to 1013 to give field Pressure Altitude. Then read the temperature on the Outside Air Temperature (OAT) gauge. Using this temperature and field Pressure Altitude, you can use a Navigation Computer to determine equivalent DA.

However, you may be flight planning away from the field, without access to the aircraft altimeter and OAT gauge.

If an aerodrome forecast (TAF) is available for your departure field, you could use the forecast 3-hour QNHs and temperatures to determine a forecast Pressure Altitude and Density Altitude.

However, provided an expected field QNH (from a TAF or a TV weather forecast) is not significantly lower than the standard sea level ISA pressure of 1013 Hpa, you can safely assume that Indicated Altitude equals Pressure Altitude, ie, Field Elevation equals Field Pressure Altitude.

If a forecast QNH is less than, say, 1005 Hpa, subtract the forecast QNH from 1013, multiply by 30, and add the result to your field elevation to get field Pressure Altitude.

TEMPERATURE, DENSITY ALTITUDE AND AIRCRAFT PERFORMANCE

Although a QNH which is different from the standard pressure will not cause any dramatic variations in aircraft performance, temperatures higher than ISA can have a significant effect. Each 1ºC difference is equal to 120 feet, so a temperature of ISA +10 means that the DA is equal to the field Pressure Altitude plus 1200 feet.

If the actual temperature is ISA + 20 (not unusual in summer), the DA will be equal to field Pressure Altitude plus 2,400 feet.

As an example, if you were departing from an airfield with an elevation of, say, 2,200 feet with a QNH of 1000 Hpa and a temperature of 30ºC, your un-supercharged engines would produce a power equivalent to 5,000 feet in the ISA - with a noticeable effect on take-off distance and climb performance!

You could use the Declared Density Altitude Charts in CAO 20.7.0 to determine the Field Density Altitude, but we have a suggested, and simpler, alternative.

DENSITY ALTITUDE CONVERSION CHART

Appendix 5 is a chart which enables an Indicated Altitude or a calculated Pressure Altitude to be converted to a Forecast Density Altitude with reasonable accuracy in the absence of an actual or forecast surface temperature.

To convert field elevation to a reasonably accurate DA, first obtain the 10,000 foot temperature from the Area Forecast (ARFOR). These are expressed as PS (plus) or (MS) minus temperatures.

Enter Appendix 5 with the Indicated Altitude or calculated Pressure Altitude on the horizontal axis, move vertically to the 10,000 feet ARFOR temperature, then move horizontally across to the left-hand axis to find the approximate equivalent Density Altitude.

Calculation of maximum TOW to give a required asymmetric Climb Gradient after Take-off

Having converted the field elevation to an equivalent Density Altitude, you can now use the POH Single-engine Climb Performance data to determine the maximum weight for safe asymmetric climb performance immediately after take-off.

This data is located in the Performance Section of the POH. It may be presented in graphical format; an extract from the Beech Baron POH is shown in Figure 4 - 7.

Some manufacturers also present the data in tabular form, with Pressure Altitudes in the left-hand column and the columns to the right containing the performance data at temperatures below, at and above ISA values.

Graphical Format

As an example, assume a planned take-off from an airfield elevation of 1880 feet, and an expected QNH of about 1009 Hpa. This QNH is not significantly below the standard 1013, so we can safely assume that Field Elevation equates to Field Pressure Altitude. The forecast 10,000 ft temperature from the ARFOR is PS10. From Appendix 5, the departure airfield has a forecast equivalent density altitude of approximately 3700 feet.

In this example, we need to achieve a 3% climb gradient after take-off to ensure terrain clearance in the event of an engine failure.

In the example aircraft chart (Figure 4 - 7) the data is shown in terms of climb gradient.

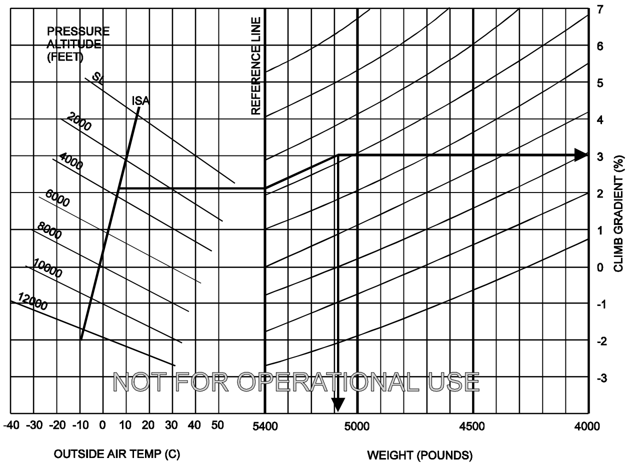


Figure 4 - 7. Single-Engine Climb Performance (Extract from POH)

However, some single engine climb performance charts present the data in terms of rate of climb, not climb gradient.

Rates of climb may be converted to climb gradients by using the rule of thumb that recommended single-engine climb speed equals the rate of climb required for a 1% climb gradient, ie, if a recommended single-engine climb speed of 80 kts produces an 80 FPM rate of climb, then this is equal to a 1% climb gradient.

For example, if the recommended single-engine climb speed is, say, 90 kts IAS, a rate of climb of 270 (3 x 90) feet per minute on the climb performance chart will closely approximate a 3% climb gradient. This assumes still air, but errs on the safe side. A head wind will give a better climb gradient.

Using Figure 4 - 7, we locate 3700 feet Density Altitude on the ISA line in the left-hand graph. Moving horizontally to the right-hand graph, we follow the guide lines to find the maximum weight which should give a 3% climb gradient - 5080 lbs. This converts to 2304 kgs, and this is the safe maximum TOW for single-engine terrain clearance under the example conditions.

CONSTRUCTION OF A MAXIMUM WEIGHT VS DENSITY ALTITUDE AND CLIMB GRADIENT GRAPH

The process of determining a safe TOW for adequate asymmetric climb performance after take-off can be streamlined by preparing a graph which shows the safe maximum weights for a range of climb gradients and Density Altitudes. This graph can also be used for the next flight planning step - predicting your ability to maintain terrain clearance in the event of an engine failure during the cruise.

It is constructed by:

a. building a table from the POH single-engine Climb Performance Chart using the form in Appendix 6 - an example for our light twin is in Figure 4 - 8,

b. plotting, for each climb gradient column, the Weight/Density Altitude points into a graph with Density Altitudes from 0 to 10,000 on the horizontal axis, and weights from Operating Weight + Fixed Reserve as a minimum to the Maximum TOW on the vertical axis.

c. joining the points for each climb gradient to produce a graph similar to Figure 4 - 9.

This graph can now be used to quickly determine a TOW for a desired asymmetric climb performance at any Density Altitude.

As an example, we will use this graph to continue completion of our sample FDC (Figure 4 - 6). Completion of this next section of the FDC is shown in Figure 4 - 10.

The planning data for this section of the FDC is:

a. Departure airfield elevation of 1800 feet AMSL (Line 12), and

b. the 10,000 feet ARFOR temperature is PS10 (Line 13).

Using this data in Appendix 5, the Forecast field DA will be 3700 feet. This is entered in the FDC at Line 14.

A 3% Climb Gradient is required for terrain clearance after take-off, and this entered at Line 15.

From Figure 4 - 9, the maximum weight for a 3% Climb Gradient at 3700 feet Density Altitude is 2309 kgs. This is entered in Line 16 of the FDC.

This revised maximum TOW should now be compared with the initial calculation of TOW in Line 10 of the FDC.

DENSITY ALTITUDE - CLIMB GRADIENT - WEIGHT DATA TABLE

VH - ______________

MAXIMUM WEIGHT (MAX TAKE-OFF WEIGHT)	2450
MINIMUM WEIGHT (OPERATING WEIGHT + FIXED RESERVE)	1730

DENSITY ALTITUDE	CLIMB GRADIENT AND WEIGHT				
	0%	0.5%	1%	2%	3%
SEA LEVEL	2450	2450	2450	2450	2450
1,000	2450	2450	2450	2450	2450
2,000	2450	2450	2450	2450	2450
3,000	2450	2450	2450	2450	2336
4,000	2450	2450	2450	2405	2268
5,000	2450	2450	2450	2291	2155
6,000	2450	2450	2430	2223	2087
7,000	2450	2450	2313	2177	2018
8,000	2450	2340	2270	2109	1973
9,000	2360	2245	2180	2041	1882
10,000	2268	2220	2132	1950	1814

Figure 4 - 8. Single Engine Climb Performance Weight Data Table

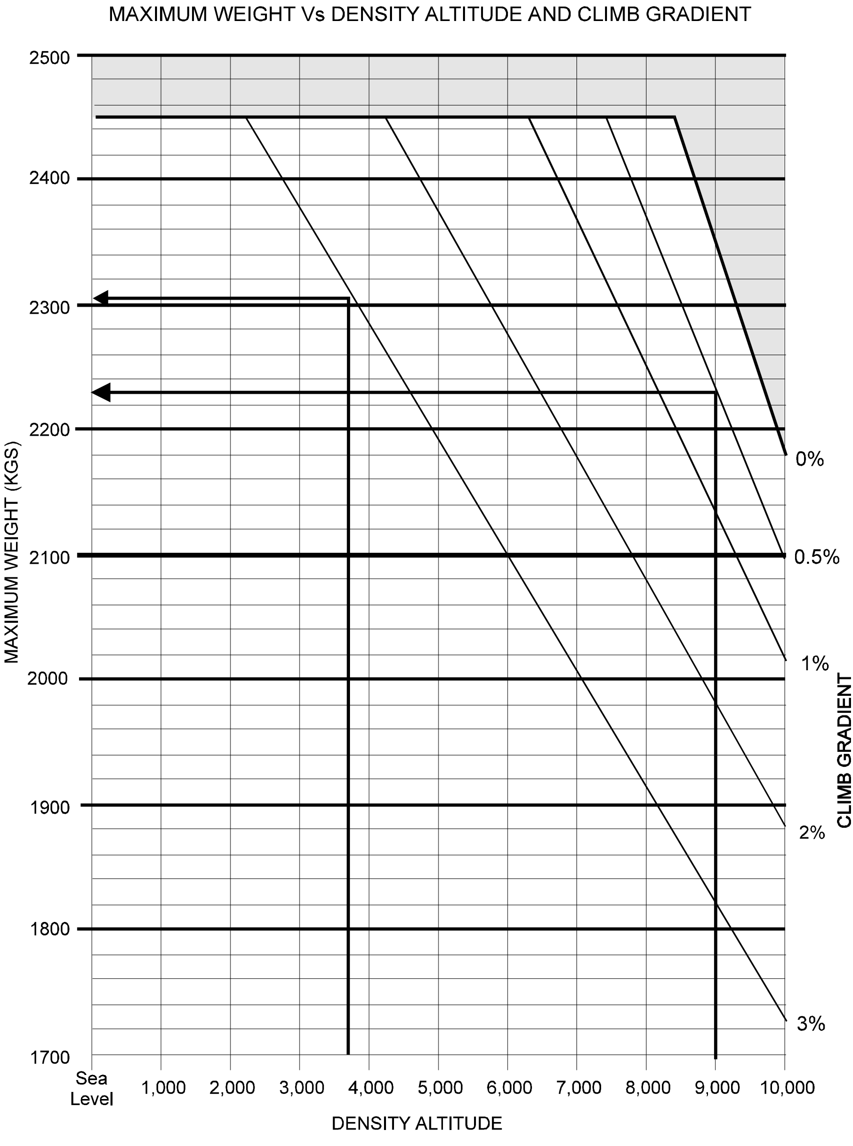
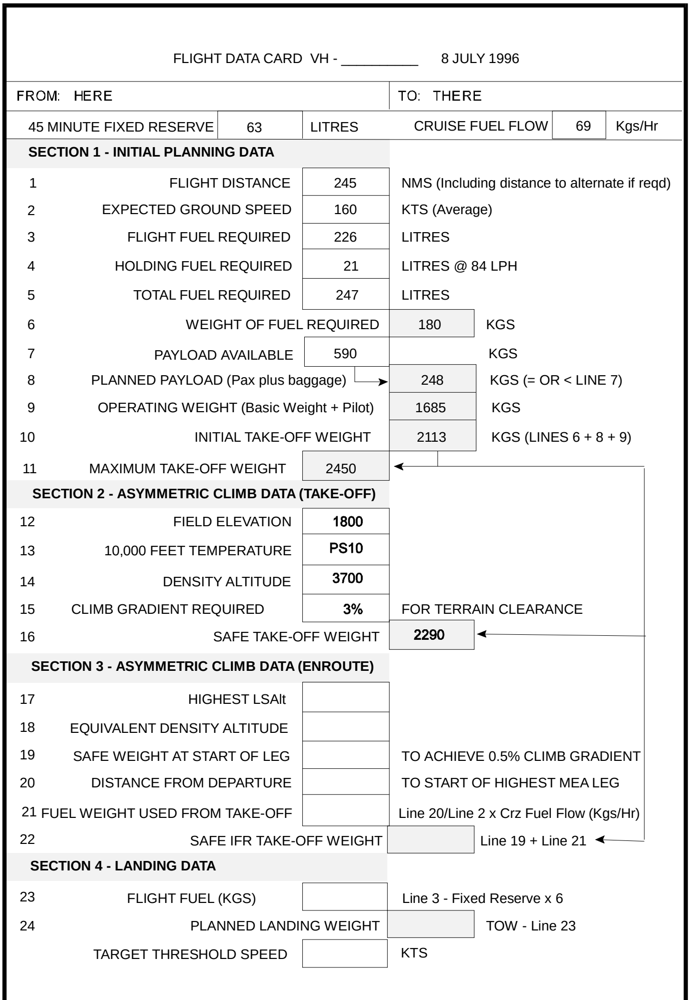


Figure 4 - 9. Maximum Weight Vs Single Engine Climb Gradient & Density Altitude

SAFE ASYMMETRIC TOW VS PAYLOAD REQUIREMENT

You may find that your safe asymmetric TOW is less than your initial TOW. In this case, unless you are prepared to accept shorter stage lengths (less fuel weight) or a reduced payload weight, you will have to accept a reduced asymmetric climb performance.



FLIGHT DATA CARD VH - __________ 8 JULY 1996

FROM: HERE | TO: THERE

45 MINUTE FIXED RESERVE 63 LITRES | CRUISE FUEL FLOW 69 Kgs/Hr

SECTION 1 - INITIAL PLANNING DATA			
1	FLIGHT DISTANCE	245	NMS (Including distance to alternate if reqd)
2	EXPECTED GROUND SPEED	160	KTS (Average)
3	FLIGHT FUEL REQUIRED	226	LITRES
4	HOLDING FUEL REQUIRED	21	LITRES @ 84 LPH
5	TOTAL FUEL REQUIRED	247	LITRES
6	WEIGHT OF FUEL REQUIRED	180	KGS
7	PAYLOAD AVAILABLE	590	KGS
8	PLANNED PAYLOAD (Pax plus baggage)	248	KGS (= OR < LINE 7)
9	OPERATING WEIGHT (Basic Weight + Pilot)	1685	KGS
10	INITIAL TAKE-OFF WEIGHT	2113	KGS (LINES 6 + 8 + 9)
11	MAXIMUM TAKE-OFF WEIGHT	2450	
SECTION 2 - ASYMMETRIC CLIMB DATA (TAKE-OFF)			
12	FIELD ELEVATION	**1800**	
13	10,000 FEET TEMPERATURE	**PS10**	
14	DENSITY ALTITUDE	**3700**	
15	CLIMB GRADIENT REQUIRED	**3%**	FOR TERRAIN CLEARANCE
16	SAFE TAKE-OFF WEIGHT	**2290**	
SECTION 3 - ASYMMETRIC CLIMB DATA (ENROUTE)			
17	HIGHEST LSAlt		
18	EQUIVALENT DENSITY ALTITUDE		
19	SAFE WEIGHT AT START OF LEG		TO ACHIEVE 0.5% CLIMB GRADIENT
20	DISTANCE FROM DEPARTURE		TO START OF HIGHEST MEA LEG
21	FUEL WEIGHT USED FROM TAKE-OFF		Line 20/Line 2 x Crz Fuel Flow (Kgs/Hr)
22	SAFE IFR TAKE-OFF WEIGHT		Line 19 + Line 21
SECTION 4 - LANDING DATA			
23	FLIGHT FUEL (KGS)		Line 3 - Fixed Reserve x 6
24	PLANNED LANDING WEIGHT		TOW - Line 23
	TARGET THRESHOLD SPEED		KTS

Figure 4 - 10 Flight Data Card with Asymmetric Climb Weight Data (Take-off)

If this will not provide terrain clearance in the event of an engine failure, your twin is little better than a single. If you are carrying passengers who have elected to fly in a twin on the assumption that it is safer than a single in the event of an engine failure, you would be wise and professionally ethical to reduce your take-off weight to ensure safe asymmetric climb performance.

However, if you and/or your passengers decide to accept the risk of being unable to maintain terrain clearance in the event of an engine failure, you should mentally prepare yourself for a possible forced landing, and identify the most favourable terrain for this purpose beyond the departure end of the runway!

In our example (Figure 4 - 10), the safe asymmetric TOW is greater than the initial TOW, and we could therefore continue our flight planning without reducing the fuel weight, and with a reasonable expectation that we would be able to maintain terrain clearance in the event of an engine failure after take-off.

MAXIMUM WEIGHT FOR ASYMMETRIC CLIMB PERFORMANCE IN THE CRUISE

If you are planning IFR, you should also ensure that you can maintain Lowest Safe Altitude (LSA) in the event of an engine failure. To do this, you should determine the maximum weight which will enable you to achieve a 0.5% climb gradient (Service Ceiling) at the highest LSA on your planned route if an engine fails.

You first need to convert the highest LSA to a density altitude. This can be done quickly using the ARFOR 10,000 feet temperature and Appendix 5.

Enter the chart with the LSA, move vertically to the ARFOR 10,000 feet temperature and read the equivalent Density Altitude from the left-hand scale.

Having determined the equivalent Density Altitude, use either the POH asymmetric climb performance chart or a custom-made Density Altitude-climb gradient-weight graph (Figure 4 - 9) to determine the maximum safe weight at the start of the route segment with the highest LSA.

However, the maximum weight determined for the start of the highest LSA route segment is not the maximum TOW.

In many cases, the highest LSA route segment may not be reached until well after take-off. Therefore, to determine the maximum TOW you will need to calculate the weight of fuel used to this point in the flight, and then add this figure to the safe weight for the start of the highest LSA route segment.

Determining Safe Maximum TOW for Asymmetric Enroute Climb performance

As an example of how to determine this third possible TOW for IFR operations, we will complete an IFR Flight Data Card.

We will assume that we are planning for the same flight as in the previous VFR example, but we have used a Fuel Vs Distance and Groundspeed Graph which provides for a 15% increase in cruise fuel flow to give an IFR Variable reserve. There is also a requirement to carry 30 minutes Holding Fuel.

Therefore, the revised figures in Section 1 of the FDC will be:

a. Flight fuel required (IFR) = 253 litres (Line 3)

b. Holding fuel required = 42 litres (Line 4)

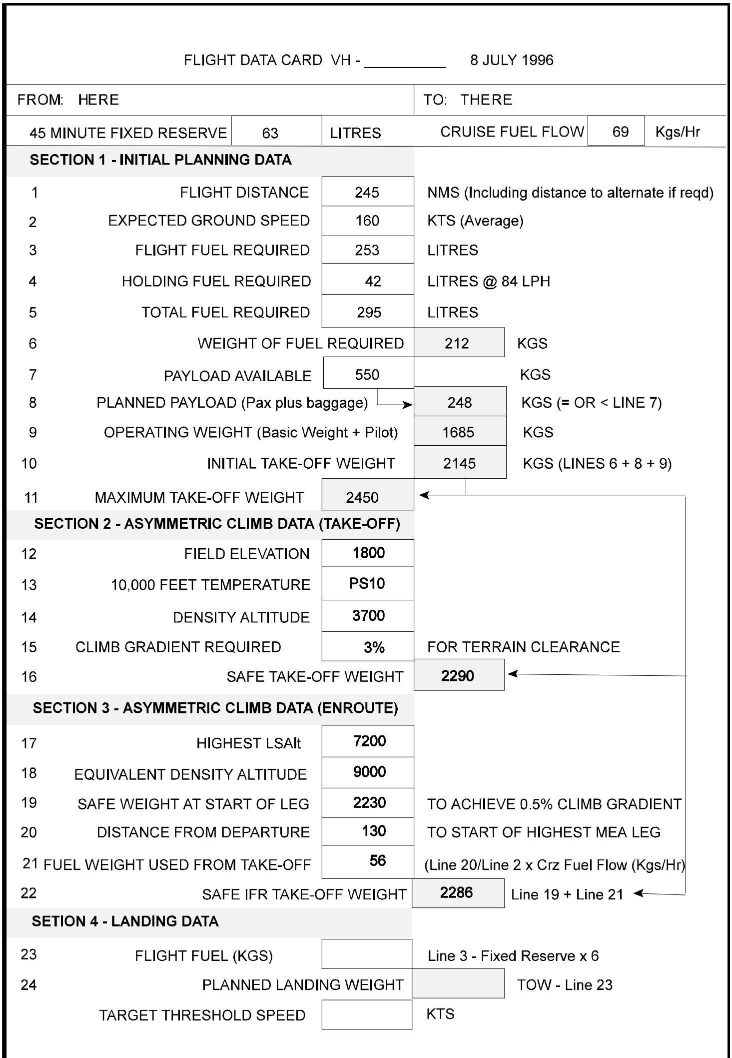
c. Total fuel required = 295 litres (Line 5)

d. Fuel Weight = 212 Kgs (Line 6)

e. Payload Available = 550 Kgs (Line 7)

f. Planned Take-Off Weight = 2145 Kgs

We will also assume that the POH does not specify a reduced Maximum TOW for IFR operations, although for some light twins a reduced maximum TOW is specified.



FLIGHT DATA CARD VH - __________ 8 JULY 1996

FROM: HERE | TO: THERE

45 MINUTE FIXED RESERVE 63 LITRES | CRUISE FUEL FLOW 69 Kgs/Hr

SECTION 1 - INITIAL PLANNING DATA			
1	FLIGHT DISTANCE	245	NMS (Including distance to alternate if reqd)
2	EXPECTED GROUND SPEED	160	KTS (Average)
3	FLIGHT FUEL REQUIRED	253	LITRES
4	HOLDING FUEL REQUIRED	42	LITRES @ 84 LPH
5	TOTAL FUEL REQUIRED	295	LITRES
6	WEIGHT OF FUEL REQUIRED	212	KGS
7	PAYLOAD AVAILABLE	550	KGS
8	PLANNED PAYLOAD (Pax plus baggage)	248	KGS (= OR < LINE 7)
9	OPERATING WEIGHT (Basic Weight + Pilot)	1685	KGS
10	INITIAL TAKE-OFF WEIGHT	2145	KGS (LINES 6 + 8 + 9)
11	MAXIMUM TAKE-OFF WEIGHT	2450	
SECTION 2 - ASYMMETRIC CLIMB DATA (TAKE-OFF)			
12	FIELD ELEVATION	1800	
13	10,000 FEET TEMPERATURE	PS10	
14	DENSITY ALTITUDE	3700	
15	CLIMB GRADIENT REQUIRED	3%	FOR TERRAIN CLEARANCE
16	SAFE TAKE-OFF WEIGHT	2290	
SECTION 3 - ASYMMETRIC CLIMB DATA (ENROUTE)			
17	HIGHEST LSAlt	7200	
18	EQUIVALENT DENSITY ALTITUDE	9000	
19	SAFE WEIGHT AT START OF LEG	2230	TO ACHIEVE 0.5% CLIMB GRADIENT
20	DISTANCE FROM DEPARTURE	130	TO START OF HIGHEST MEA LEG
21	FUEL WEIGHT USED FROM TAKE-OFF	56	(Line 20/Line 2 x Crz Fuel Flow (Kgs/Hr)
22	SAFE IFR TAKE-OFF WEIGHT	2286	Line 19 + Line 21
SETION 4 - LANDING DATA			
23	FLIGHT FUEL (KGS)		Line 3 - Fixed Reserve x 6
24	PLANNED LANDING WEIGHT		TOW - Line 23
	TARGET THRESHOLD SPEED		KTS

Figure 4 - 11 IFR Flight Data Card with Section 3 Completed

The completed sample IFR FDC is in Figure 4 - 11.

The additional data assumed for enroute asymmetric climb data section of the FDC is:

a. a highest LSA of 7,200 feet, and

b. the start of this route segment is 130 nms after take-off.

These figures are entered in the FDC at Lines 17 and 20.

Using Appendix 5, we determine that the LSAlt of 7,200 feet is equal to a Density Altitude of 9,000 feet using the 10,000 feet ARFOR temperature of PS 10. This equivalent Density Altitude is entered in the FDC at Line 18.

Using Figure 4 - 9, the maximum weight to achieve a 0.5% Climb Gradient at a Density Altitude of 9,000 feet is 2230 Kgs. This figure is entered in the FDC at Line 19.

The fuel used over a distance of 130 nms is calculated by dividing the distance (Line 20) by the groundspeed (Line 2). This figure is then multiplied by the VFR cruise fuel flow of 96 LPH. This gives the fuel quantity (78 litres) used since take-off, and this is converted to weight by multiplying by 0.72, to give a final result of 56 kgs. This figure is entered in the FDC at Line 21.

Adding Line 19 to Line 21 gives a figure of 2286 kgs - this is the maximum TOW which would enable you to maintain the highest LSA in the event of an engine failure on that route segment.

In practice, this maximum TOW could be less than your desired TOW based on fuel and passenger load (Line 10), and/or less than that required for asymmetric terrain clearance immediately after take-off (Line 16).

You can legally take-off at a weight which would not provide asymmetric terrain clearance after take-off. However, you cannot legally take-off for IFR charter or aerial work flights at a weight which would give less than a 1% climb gradient at 5,000 feet Density Altitude if an engine fails (Appendix 2).

For IFR private flights, the requirement is to be able to maintain level flight up to 5,000 feet Density Altitude in the event of an engine failure.

Because these IFR minimum climb gradients are a mandatory CASA requirement, the validity of your insurance policy almost certainly depends on you observing them for IFR flight planning!

TAKE-OFF AND LANDING DISTANCES REQUIRED

Your final TOW consideration is to ensure that the Take-Off Distance Required (TODR) for your planned TOW is not greater than the Take-off Distance Available (TODA).

In many, if not most cases, you will know that your departure and destination airfield runway lengths available are well in excess of those required at maximum weights and in the prevailing or forecast conditions. However, there are occasions when runway lengths are possibly marginal, and on these occasions the distances available and required should be checked as part of the flight planning process.

In determining the TODR and Landing Distance Required (LDR), you should use the Take-off and Landing Distance Charts in the POH.

CALCULATING TODR FOR A INTERMEDIATE LANDING FIELD

If your flight includes an intermediate landing and take-off at a possibly marginal length field, you should also calculate the TODR for that field before you start the flight.

A number of accidents have occurred where pilots have attempted to take-off from an intermediate field which was long enough for landing but not long enough for a subsequent take-off. The time to find this out is before you start the flight, not after you arrive — and definitely not during the subsequent take-off from the intermediate field!

If you need to determine the TODR for an intermediate field, assume nil wind and, if the field has more than one strip, calculate using the longest one available. For take-off weight, use your planned landing weight less an allowance for taxi fuel.

TODR/LDR FLIGHT PLANNING AID

You can construct a "worst case" planning guide to streamline the TODR/LDR calculation process - an example is shown in Figure 4 - 12.

WORST CASE TODR/LDR DATA

VH - ___________

ASSUMPTIONS:

Take-off:

1. Field Density Altitude = 5,000 feet AMSL
2. Hard Surface, Level Runway
3. Nil Wind
4. Maximum Take-off Weight
5. Take-off Safety Speed = 94 kts
6. Zero Flap Take-off

Landing:

7. Approach Speed = 96 kts
8. Full Flap Approach

TAKE-OFF DISTANCE REQUIRED (METRES)	762
LANDING DISTANCE REQUIRED (METRES)	853

Figure 4 - 12. Worst Case TODR/LDR Data

Assuming:

a. the highest density altitude you could reasonably expect in practice,

b. a level, hard surface runway,

c. nil wind, and

d. maximum TOW,

determine from the AFM or the POH performance charts the TODR and LDR for this "worst case", and enter these figures in the planning guide.

If the TODAs and LDAs are greater and the departure /intermediate field density altitudes are less than your "worst case" data, then the distances available are adequate. However, if the distances actually available or the forecast field density altitudes are close to the "worst case" data, or the runway(s) are not level, hard surfaces, you should do TODR/TODA and/or LDR/LDA calculations to ensure safe take-offs and landings.

CLIMB AND CRUISE PLANNING

CLIMB LEG PLANNING

Climbs to cruising altitude may be planned separately, and the Performance Section of most POHs contain a Climb Distance - Time - Fuel Used chart.

However, to save flight planning time, a common practice is to plan the complete flight using cruise ground speed for the full distance, and then add additional time to each climb leg to allow for the decreased TAS in the climb.

As a rule of thumb, add one minute for each 1,000 feet in the climb.

SELECTION OF CRUISING ALTITUDE

The selection of optimum cruising altitude depends on many factors.

Highest TAS

For any cruise power setting in an un-supercharged aircraft, the highest TAS will be obtained at the altitude at which the throttles are fully open.

Above this “full throttle” altitude, the required power cannot be maintained and the TAS will reduce.

If the highest TAS is required, a power setting of about 75% would be used and the aircraft cruised at the “full throttle” altitude for this power setting, which is typically about 6,000 feet Density Altitude. Above this altitude the high power setting cannot be maintained and the TAS will reduce.

In any event, flights over short distances, eg, less than about 100 nms, will usually be conducted more economically at altitudes below “full throttle” height, to reduce the time spent at the lower climb TAS and high climb power.

IFR Flight

For IFR flights, the overriding consideration in selection of cruising altitude is the Lowest Safe Altitude (LSA) on each route segment.

There may also be a specified minimum enroute altitude on certain IFR route segments to ensure adequate reception of “line-of-sight” radio navigation aids.

VFR Flight

For VFR flights, the elevation of enroute terrain and forecast cloud base will be primary considerations.

Forecast Wind and Turbulence

Significant changes in forecast wind velocity with increasing altitude, or the possibility of low level turbulence may indicate that a flight should be conducted above the "full throttle" for maximum TAS, to achieve a higher ground speed or to ensure a smooth flight.

Hemispheric Cruising Altitudes

In any event, the cruising altitude selected for each route segment must conform to an appropriate VFR or IFR hemispheric altitude as specified in AIPs.

Therefore, the selection of an appropriate cruising altitude depends on much more than just optimum "still air" aircraft performance.

CRUISE POWER SETTINGS

Once a cruise altitude has been chosen, the desired cruise TAS and associated power setting needs to be determined. Most POHs will provide a chart which correlates a percentage of MCP with TAS. For maximum range, eg, inter-island or long distance remote area flights, a relatively low power setting (about 55% of MCP) may be required.

This gives a relatively low TAS and consequently a long flight time, and is rarely used in practice.

Although the engines of most light twins can be operated continuously at full power, 75% MCP is recommended as a normal maximum cruise power setting to avoid excessive engine wear and a possibly reduced time between engine overhauls.

Therefore, a power setting between 55% and 70% MCP is normally used as a compromise between reduced flight time and fuel economy. Using a lower cruise power means that full throttle height will be higher, but maximum TAS will be less.

Whatever the power setting chosen, there is a range of manifold pressure/RPM settings which will give the desired power.

RPM - MANIFOLD PRESSURE (MAP) COMBINATIONS

It has been traditional practice to use approximately “square” cruise power settings, eg, 2300 RPM/23" MAP.

However, piston engines are designed to operate most efficiently at relatively high manifold pressure - low RPM combinations.

The higher manifold pressures provide better seating of piston rings and therefore minimise oil consumption and, in combination with relatively low RPM, they also minimise high inertia loads on main and connecting rod bearings.

Using the lowest RPM possible also reduces the “piston-miles” traveled in any given time, and reduces engine wear.

RPM - Manifold Pressure Limitations

However, engine manufacturers may place limits on the maximum manifold pressure which can be used at given engine RPM to avoid “over-boosting”.

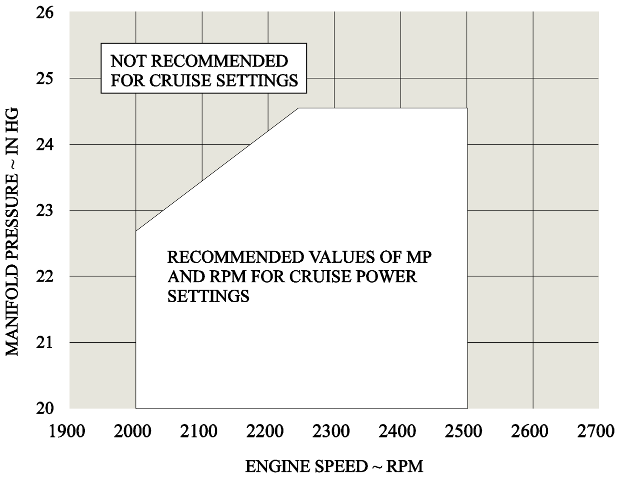


Figure 4 - 13. Typical RPM/MP Envelope

These limitations will be shown either in the aircraft manufacturer's POH or the engine manufacturer's Owner's Handbook. Figure 4 - 13 shows a typical RPM/MAP envelope.

There may also be a restricted RPM range for continuous operation with some engine-propeller combinations to avoid vibration problems. If this type of limitation is applicable, the restricted RPM range will be marked on the RPM indicator by a yellow band.

Provided an engine is operated within these manufacturers limits, the lowest RPM/highest allowable manifold pressure for any power setting will provide the following:

a. The most favourable internal engine operating conditions, ie, least wear/least oil consumption;

b. The quietest cabin environment;

c. A slightly reduced fuel consumption (less power strokes per minute); and

d. A reduced tacho time per hour - if this is the time on which maintenance periods is based, an extension of about 10% of the flight time between 100 hourly inspections is both possible and legal.

If you experience some vibration at the lower RPM settings, have your engine/propeller balanced by an Engineer using an electronic balancer. This is a simple, low cost procedure which will provide smooth flight and save potential damage to engine components such as engine and engine component mounting brackets - this type of damage is a relatively frequent cause of increased periodic inspection costs.

Full Throttle Height Considerations

The only “down side” to the use of relatively low RPM/high manifold pressure combinations is that the “full throttle” altitude is a function of selected MAP and RPM - the lower the RPM, the lower will be the full throttle height for any power setting

Higher power settings, eg, above 65% MCP, may not be achievable at the lowest permissible (and desirable) RPM above about 5 - 6000 feet density altitude. If you wish to cruise above this altitude at the lowest permissible RPM, you will have to accept a slightly lower TAS and, consequently, a slightly longer flight time.

If this is unacceptable, you can increase RPM to the extent necessary to achieve the desired power for the TAS desired. However, if flight above the low RPM/full throttle height is not necessary, or a slightly longer flight time is acceptable, the low RPM/high manifold pressure combination (within published limits) is highly recommended.

CALCULATION OF POINTS OF NO RETURN (PNR) AND CRITICAL POINTS (CP)

A multi-engine aircraft provides a significant margin of safety on long flights between remote airfields, particularly over water.

However, there may be occasions when a landing at the planned destination is not possible due to weather, and insufficient fuel is available to fly to the destination, attempt an approach and then divert to an alternate.

In this case, the planning must include calculation of a Point of No Return (PNR). The PNR is also known as the Point of Safe Return (PSR). This is the furthest point along track that you can fly towards the destination and have sufficient fuel to divert to an alternate, with safe reserves on arrival. In other words, it is your last chance to assess your prospect of a successful approach and landing at your destination, and decide whether to go on or to divert. If any doubt exists, divert to the alternate.

POINT OF NO RETURN

There are a number of methods which can be used to calculate a PNR/PSR, but the one most favoured uses what are called Specific Fuel Flows (SFF).

Quite simply, these are derived by dividing the planned cruise fuel flow by the expected ground speeds towards the destination and towards the alternate field, and the result is the fuel required per nautical mile traveled in each direction.

The general formula used to calculate the distance to the PNR from the Alternate is:

$$\text{Distance to PNR} = \frac{\text{Flight Fuel Available (Alternate to Destination)}}{\text{SFF (To Destination)} + \text{SFF (To Alternate)}}$$

The Flight Fuel Available (FFA) is the Usable Fuel on Board (FOB) minus the Fixed Reserve (FR), any holding fuel and any taxi allowance.

Variable Reserve

For all IFR flights, and for all extended range flights requiring a PNR, you should allow an additional fuel reserve to provide for winds stronger than forecast or for a higher fuel consumption than that specified in the POH. Conventionally, this is achieved by reducing the Flight Fuel Available figure by 15%, ie, dividing the FFA by 1.15.

CALCULATION OF PNR WHEN THE ALTERNATE IS THE DEPARTURE FIELD

This is the simplest situation to calculate.

As an example, let's assume a flight from A to B, with A as the alternate field. The distance A to B is 500 nms. Max range cruise power will be used, giving a fuel flow of 80 litres/hr, and this fuel flow will also be used for a Fixed Reserve and any holding.

At this power setting the planned TAS is 160 kts and a 25 kt tailwind is forecast A to B. Therefore, the ground speed to B is 185 kts, with a return ground speed to A of 135 kts.

The ground specific fuel flow (GSFF) “out” will be 0.43 litres/nm (80/185), and the GSFF “home” will be 0.59 litres/nm (80/135). The sum of the GSFFs “out” and “home” is 1.02.

The weight of passengers and baggage we want to carry is 480 kgs. From Fig 4 - 5, we can also carry 390 litres of usable fuel without exceeding the Maximum AUW. For this flight, maximum AUW will enable adequate asymmetric climb performance on take-off or enroute.

To establish the Flight Fuel Available for the PNR calculation, we must subtract from the Usable FOB the Fixed Reserve (60 litres), the taxi fuel (10 litres) and the climb allowance (11 litres). The forecast for a possible return to A does not indicate the need for any holding fuel.

Therefore, the FFA is 390 - (60+10+11): 309 litres.

This figure is now divided by 1.15 to provide a Variable Reserve, giving a final FFA of 269 litres.

The distance to the PNR from A is therefore 269 ÷ 1.02 = 264 nms from A.

CALCULATION OF A PNR WHEN THE ALTERNATE IS ON TRACK BETWEEN THE DEPARTURE POINT AND THE DESTINATION

The calculation of a PNR for this case is essentially the same as before, except that the “datum” for calculation is over the alternate.

We will use the previous example of a flight from A to B over a distance of 500 nms, but with the possible alternate C 190 nms along track towards B, ie, the distance from C to B is 310 nms.

The other planning data remains the same as in the previous example , ie:

a. Flight Fuel Available at A = 269 litres (after allowing for a Variable Reserve)

b. Cruise Fuel Flow = 80 litres/hr

c. Ground Speed Out = 185 kts

d. Ground Speed Home = 135 kts

We first determine how much fuel is required to fly from A to overhead C. This is equal to the distance A to C (190 nms) multiplied by the GSFF “out” (0.43 litres/nm): 82 litres.

This is subtracted from the Flight Fuel Available A to B (269 litres) to give a Flight Fuel Available C to B of 187 litres.

The distance of the PNR from C is therefore 187 ÷ 1.02: 183 nms. This is 127 nms short of B, and if the aircraft flies beyond this point there will not be sufficient fuel to return to C with the fixed reserve intact.

CALCULATION OF AN ASYMMETRIC PNR

For flights over water or inhospitable terrain you should know how far along track you can proceed, experience an engine failure and return/divert to an alternate with safe fuel reserves. This is called an asymmetric PNR.

To determine this point, you need to know what TAS your aircraft will achieve with an engine shutdown, the propeller feathered and the fuel flow of the operating engine(s) at an appropriate power setting.

The POH does not normally provide this data, and you must normally obtain it by in-flight test. You will find the results intriguing.

At an altitude of, say, 6,000 feet with 1013 QNH set, establish zero thrust on one engine. This is the equivalent of a feathered propeller, and the appropriate MAP/RPM settings for zero thrust are usually specified in the Emergencies (Red Tab) Section of the POH.

An appropriate power setting for the operating engine is 75% of Maximum Continuous Power (MCP) or Climb Power; this is usually the highest power setting at which you can lean the mixture.

After the speed has stabilised, note the IAS, the OAT and, if the engines are injected, the Fuel Flow on the operating engine with the mixture leaned to the manufacturer's specification.

After landing from this flight test, calculate the TAS applicable to the IAS, OAT and Pressure Altitude of the test. Then calculate the Air Specific Fuel Flow (ASFF) - Litres per Air Nautical Mile - by dividing the recorded/POH derived operating engine Fuel Flow by the TAS.

You may find that this ASFF is less than the ASFF with all engines operating at maximum range power setting, ie, for a given quantity of fuel available, you may be able to fly further with one engine shut down than with all engines operating!

This means that an asymmetric PNR may be further along track than an “all-engines-operating” PNR.

However, this assumes that all the usable flight fuel on board can be made available to the operating engine, ie, the fuel crossfeed system has been checked before take-off and is functioning correctly.

To illustrate, we will use the data from the previous PNR example, ie, a flight from A to B overflying an alternate C.

From flight test, the aircraft has an asymmetric TAS of 125 kts with the operating engine, set at 75% MCP, using 60 litres/hour.

The additional data required is:

a. Flight Fuel Available over C = 189 litres (includes Variable Reserve allowance)

b. Cruise Fuel Flow (all engines) = 80 litres/hr

c. Ground Speed Out (all engines: 160 kts TAS + 25 kt tailwind) = 185 kts

d. Cruise Fuel Flow (Asymmetric) = 60 litres/hr

d. Ground Speed Home (asymmetric: 125 kts TAS - 25 kt headwind) = 100 kts

e. GSFF “out” (80 ÷ 185) = 0.43 litres/gnm

f. GSFF “home” (60 ÷ 100) = 0.6 litres/gnm

Therefore, the distance to the asymmetric PNR from C is 187 ÷ (0.6 + 0.43): 182 nms. This compares to the “normal” PNR of 183 nms.

CALCULATION OF A CRITICAL POINT

While the distance to a PNR is dependent on fuel availability and fuel flow, the distance to a Critical Point (CP) is independent of fuel considerations and is based on groundspeeds only.

The CP is also known as the “Equi-time Point” (ETP), because it is the point along track from where it will take the same time to continue to the planned destination as it will to divert/return to an alternate.

The CP/ETP is normally associated with an abnormal flight condition or an emergency where there is a need to minimise the time before landing. For example, a passenger who falls ill, or an engine failure in flight with a need to minimise the flight time on the remaining engine(s).

The general formula used to calculate the distance of a CP/ETP from an Alternate is:

$$\text{Distance to CP} = \frac{\text{Distance (Alt to Dest) x Groundspeed to Alt}}{\text{Groundspeed to Dest + Groundspeed to Alt}}$$

In the event of an engine shutdown, the TAS will be reduced significantly, with a similar effect on the groundspeed “home”.

To illustrate, we will calculate an “engine-out” (asymmetric) CP/ETP for the previous example flight.

The required data is:

- Distance Alternate (C) to Destination (B) = 310 nms
- Asymmetric TAS = 125 kts
- Tailwind component = 25 kts
- One Engine Groundspeed “on” to B = 150 kts
- One Engine Groundspeed “back” to C = 100 kts

The distance to the CP from C is therefore (310 x 100) ÷ (150 + 100) = 124 nms, which is 186 nms short of B. From this point the time on to B is 1.24 hours (186/150), and the time back to C is also 1.24 hours (124/100).

Figure 4 - 17 shows the relative positions of the Normal PNR, the Asymmetric PNR and the Asymmetric CP for the flight used as the example.

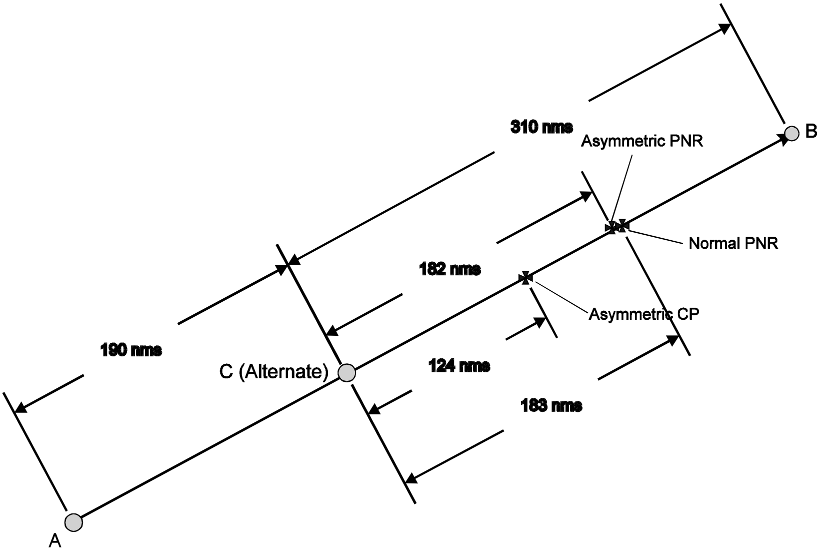


Figure 4 - 17. Normal and Asymmetric PNRs, Asymmetric CP Along Track Alternate

APPENDIX 1

FLIGHT DATA CARD VH - __________

FROM:

TO:

45 MINUTE FIXED RESERVE ☐ LITRES

CRUISE FUEL FLOW ☐ Kgs/Hr

SECTION 1 - INITIAL PLANNING DATA			
1	FLIGHT DISTANCE	☐	NMS (Including distance to alternate if reqd)
2	EXPECTED GROUND SPEED	☐	KTS (Average)
3	FLIGHT FUEL REQUIRED	☐	LITRES
4	HOLDING FUEL REQUIRED	☐	LITRES
5	**TOTAL FUEL REQUIRED**	☐	LITRES
6	WEIGHT OF FUEL REQUIRED	☐	KGS
7	**PAYLOAD AVAILABLE**	☐	KGS
8	PLANNED PAYLOAD (Pax plus baggage)	☐	KGS (= OR < LINE 7)
9	OPERATING WEIGHT (Basic Weight + Pilot)	☐	KGS
10	**INITIAL TAKE-OFF WEIGHT**	☐	KGS (LINES 6 + 8 + 9)
11	**MAXIMUM TAKE-OFF WEIGHT**	☐	
SECTION 2 - ASYMMETRIC CLIMB DATA (TAKE-OFF)			
12	FIELD ELEVATION	☐	
13	10,000 FOOT ARFOR TEMPERATURE	☐	
14	DENSITY ALTITUDE	☐	
15	CLIMB GRADIENT REQUIRED	☐	FOR TERRAIN CLEARANCE
16	**SAFE TAKE-OFF WEIGHT**	☐	
SECTION 3 - ASYMMETRIC CLIMB DATA-(ENROUTE)			
17	HIGHEST LSA	☐	
18	EQUIVALENT DENSITY ALTITUDE	☐	
19	SAFE WEIGHT AT START OF LEG	☐	TO ACHIEVE 0.5% CLIMB GRADIENT
20	DISTANCE FROM DEPARTURE	☐	TO START OF HIGHEST MEA LEG
21	FUEL WEIGHT USED FROM TAKE-OFF	☐	Line 20/Line 2 x Crz Fuel Flow (Kgs/Hr)
22	SAFE IFR TAKE-OFF WEIGHT	☐	Line 19 + Line 21
LANDING DATA			
23	FLIGHT FUEL (KGS)	☐	Line 3 - Fixed Reserve x 6
24	PLANNED LANDING WEIGHT	☐	TOW - Line 23
	TARGET THRESHOLD SPEED	☐	KTS

APPENDIX 2

DISTANCE AND FUEL REQUIRED DATA - 60% MCP

N __________

BASIC DATA:

ASSUMED CRUISE ALTITUDE ________ FEET
TRUE AIRSPEED ________ KNOTS
CRUISE FUEL FLOW GPH

CLIMB FUEL ALLOWANCE = .12 x CRUISE FUEL FLOW

FIXED RESERVE = .75 x CRUISE FUEL FLOW

FLIGHT FUEL = DISTANCE/GROUNDSPEED x CRZ FUEL FLOW

GROUNDSPEEDS								
MIN & MAX DISTANCES	40	500	40	500	40	500	40	500
START/TAXY/TAKEOFF FUEL								
CLIMB FUEL ALLOWANCE								
FIXED RESERVE								
FLIGHT FUEL								
TOTAL FUEL REQUIRED								

APPENDIX 3

PAYLOAD AVAILABLE AND FUEL WEIGHT TABLE

N __________

AIRCRAFT WEIGHTS

	MAXIMUM TOW			From POH
	BASIC WEIGHT			From POH (Basic Weight plus oil)
	PILOT PLUS EQUIPMENT			
	OPERATING WEIGHT			Basic Weight plus pilot
1	**USEFUL LOAD**			Max TOW - Operating Weight

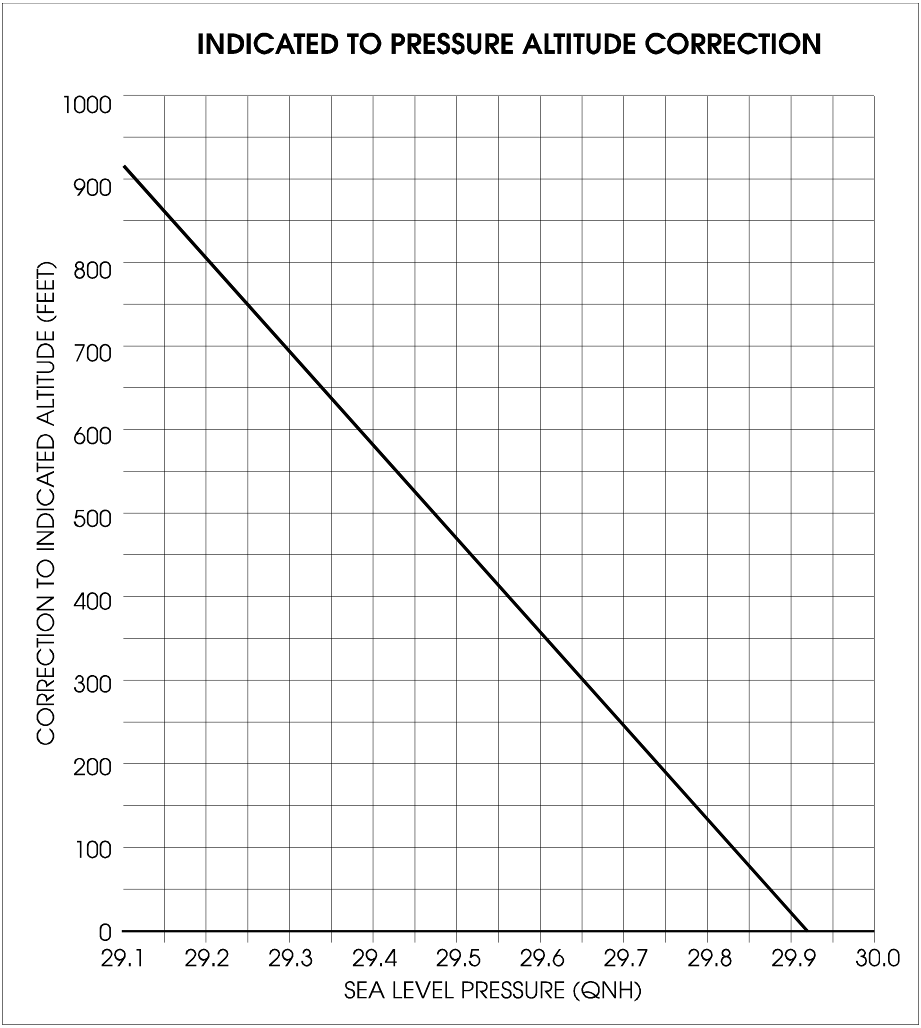
FUEL REQUIRED FOR MAXIMUM AND MINIMUM DISTANCES

2	MINIMUM FUEL REQUIRED		Graph Points A and C
3	MAXIMUM FUEL REQUIRED		Graph Points B and D

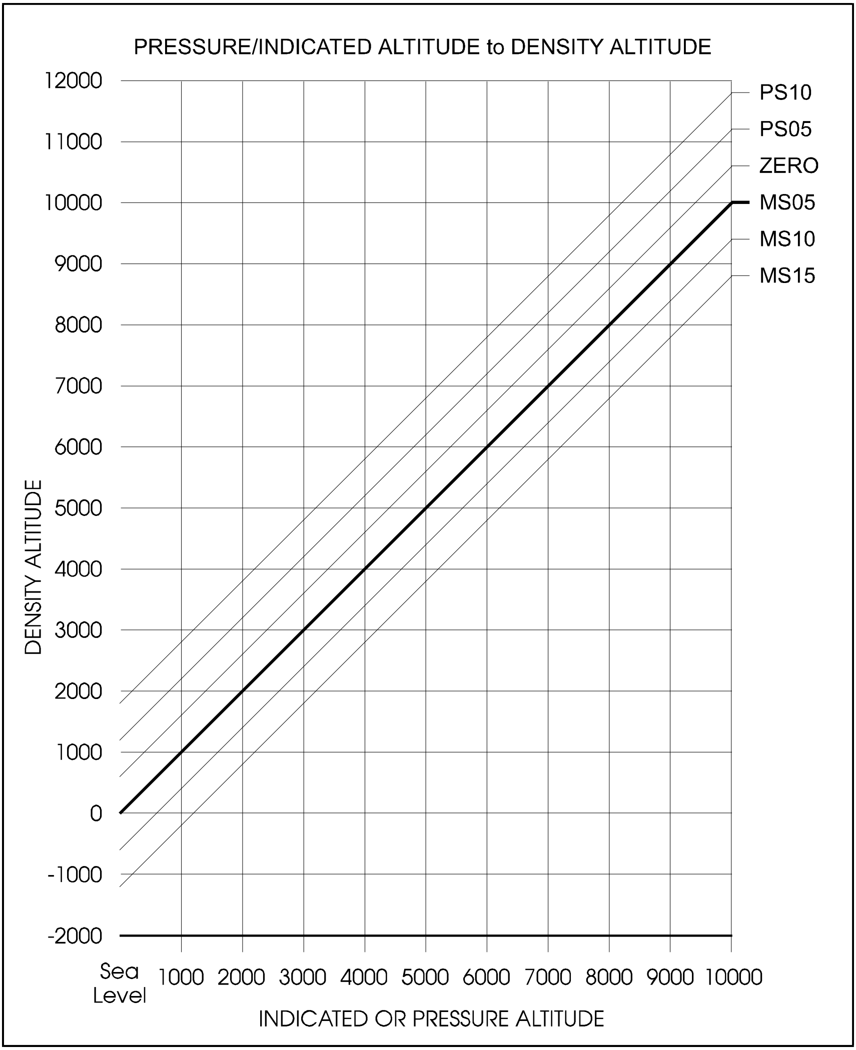
MAXIMUM AND MINIMUM WEIGHTS

4	MIN FUEL WEIGHT (LINE 2 x 6)		Graph Point C
5	MAX PAYLOAD (LINE 1 - LINE 4)		Graph Point A
6	MAX FUEL WEIGHT (LINE 3 x 6)		Graph Point D
7	MIN PAYLOAD (LINE 1 - LINE 6)		Graph Point B

APPENDIX 4


INDICATED TO PRESSURE ALTITUDE CORRECTION
CORRECTION TO INDICATED ALTITUDE (FEET)
1000
900
800
700
600
500
400
300
200
100
0
29.1
29.2
29.3
29.4
29.5
29.6
29.7
29.8
29.9
30.0
SEA LEVEL PRESSURE (QNH)

APPENDIX 5


PRESSURE/INDICATED ALTITUDE to DENSITY ALTITUDE
12000
11000
10000
9000
8000
7000
6000
5000
4000
3000
2000
1000
0
-1000
-2000
DENSITY ALTITUDE
Sea Level
1000
2000
3000
4000
5000
6000
7000
8000
9000
10000
INDICATED OR PRESSURE ALTITUDE
PS10
PS05
ZERO
MS05
MS10
MS15

MULTI-ENGINE FLIGHT MANUAL FOR PROFESSIONAL PILOTS

SECTION 4 – FLIGHT PLANNING AND PERFORMANCE

APPENDIX 6

DENSITY ALTITUDE - CLIMB GRADIENT - WEIGHT DATA TABLE

N ______________

MAXIMUM WEIGHT (MAX TAKE-OFF WEIGHT)	
MINIMUM WEIGHT (OPERATING WEIGHT + FIXED RESERVE)	

DENSITY ALTITUDE	CLIMB GRADIENT AND WEIGHT				
	0%	0.5%	1%	2%	3%
SEA LEVEL					
1,000					
2,000					
3,000					
4,000					
5,000					
6,000					
7,000					
8,000					
9,000 **10,000**					
12,000					