# ENGINE FAILURE

## HOW TO HANDLE ENGINE FAILURE IN A SINGLE OR MULTI-ENGINE AEROPLANE.

PAUL PHELAN

YOU MIGHT HAVE JUST A COUPLE of seconds to utter a brief exclamation, dump your load of superphosphate, and aim your aeroplane between those two big redgums.

At the other end of the spectrum, an engine failure at cruise in a 4-engined jet, may cause scarcely a ripple in your cockpit routine. In either event, pilot preparation will enhance your prospects of bringing the flight to a dignified end.

Of the 10,000-odd powered aeroplanes on the Australian civil register, 315 – over 3 per cent – suffered a reported engine failure in a recent 12-month sampling of BASI records, and almost certainly more went unreported. You'd get probably better odds in a sample of 10,000 family cars – but when their engines fail, it invariably happens on the ground.

The BASI information, however, shows that of those 315 events, only one resulted in a fatality; one in serious injury; and five in minor injury. The summaries also show that in many cases a more serious outcome was averted by various combinations of cool-headedness, intelligent analysis, and competent execution of emergency procedures.

What do you do when an engine fails? That depends on a large number of factors, not the least of which is your state of preparedness.

The first consideration is obviously whether you are flying a multi or a single-engined aeroplane, the latter case clearly offering a far more limited range of options. The second consideration, if you still have one or more engines providing power, is the aircraft's ability to provide a pre-defined and achievable level of engine-out performance, which in turn will very much depend on its certification category. Broadly, the four categories of engine-out considerations are:

- Single-engine.
- Light piston twin.
- Light turbine twin.
- Multi-engine transport category.

Although most of the failures in the BASI sample occurred while the aircraft was airborne, a notable number were detected in pre-flight inspections and run-ups – a reminder to those pilots who are less than thorough in their preparations for flight. As well, a number were not total powerplant failures, and allowed the pilot/s to continue to a precautionary or normal landing.

"The first action in every engine failure, is to keep flying the aeroplane", asserts an instructor who specialises in multi-engined endorsements. "That may sound obvious, but I've seen so many pilots overlook it completely while they're reacting to an engine failure."

You have to focus on keeping the aircraft under control, before you begin troubleshooting, restarting, or selecting a forced landing area. The message is: "Aviate -navigate-communicate" and it should be kept at the forefront of your consciousness, so that it becomes automatic. That's where recurrent airline pilot training has an advantage.

**Worst case – single engine:** In the worst case, that of a single-engined aeroplane, the range of available options will still vary with circumstances. A total failure at or just after take-off may or may not provide the option of landing back on the runway. If it does, the use of full flap and sideslipping should be considered in order to reduce speed and the distance covered in the glide, and to get the aircraft on the ground with the maximum possible amount of runway remaining.

Bear in mind, however, that a sideslip

Paul Phelan

considerably increases your stalling speed, and is likely to cause the higher wing to stall first, causing that wing to drop in an incipient spin close to the ground, when you least need that to happen. If you haven't practised a side-slip recently, a session with a flying instructor would be a sensible investment.

Even if the runway is not long enough to make a full-stop runway landing achievable, the option of landing on the runway, braking, and running off the end into the overshoot area at reduced speed, may be preferable to an off-airport forced landing.


Paul Phelan

But as any instructor will tell you, don't even think about trying to execute a gliding turn to land back on the runway in the opposite direction; you're already at climb speed, and your glide angle is likely to be steeper than your climb angle, so you have no spare speed to convert to height, and your height loss will increase in a gliding turn.

That doesn't mean that if engine failure occurs at a sufficient height and at the right point in the circuit, you can't reach another runway.

To be confident of reaching any selected forced landing area, it is important for single-engine pilots to practice forced landings in critical situations regularly, both from selected points in the circuit area, and in cruise at various levels. One way to do that while achieving random selection of simulated engine failure points, is to commit yourself to a simulated engine failure the next time you hear a radio transmission, or (if there is constant radio chatter) a particular word in a transmission.

In an off-airport forced landing, you must select the most suitable available area, the considerations being whether you are confident you can reach it, whether the surface is suitable, and whether it is long enough in the current conditions. Again, regular practice will give you confidence; and don't forget that any extra speed can be converted to height, or to distance travelled, while you're doing your emergency checks and selecting a suitable landing site.

As the BASI figures clearly show, it's important not to commit yourself to a forced landing without first reviewing the options. Is the engine still producing power? Can that power be used to get you to (or closer to) a suitable landing site? Have you ruled out any problems that are fixable by available actions (such as changing fuel tanks)?

One pilot, a long time ago, elected to make a precautionary landing on a golf course when he noticed the oil temperature needle pointing to zero (with oil pressure normal). The aircraft was undamaged, but legend has it that the pilot was slightly injured when he was struck by a golf club wielded by the chief flying instructor, who wanted to emphasise the improbability of a sump full of oil freezing over on a December afternoon in western NSW.

And to improve your chances in a single-engined aircraft, you should always consider planning your flight at the maximum available altitude, weather permitting, and possibly selecting a route which keeps you within gliding distance of suitable forced landing sites for the maximum possible time, even if it's not the most direct route.

**"The first action in every engine failure, is to keep flying the aeroplane, asserts an instructor who specialises in multi-engined endorsements. 'That may sound obvious, but I've seen so many pilots overlook it completely, while they're reacting to an engine failure."**

**Light twins:** While the airlines have engine failures well and truly covered, how do light twins compare?

Again, weight, altitude and temperature work against you, but there are other factors as well.

The only certification climb performance requirement for a light twin is that if it is being operated under instrument flight rules (IFR), it must have a demonstrated capability to climb at a 1 per cent gradient at 5,000ft in International Standard Atmosphere (ISA) conditions, having taken off at MTOW.

Although that capability does not guarantee any specific climb performance in any configuration, most manufacturers provide a pilot operating handbook (POH) which includes such data as single- and twin-engine climb rate and airspeed versus altitude and weight; accelerate/ stop distance, and take-off distances. However these data are not certificated, and were derived from factory testing.

Many pilots have found it informative to compare actual aircraft performance with the manufacturers' graphs, and that course of action is strongly recommended by instructors – it can be done during training, but should never be attempted at an unsafe height. It is important to remember that when conducting any such experiment, the operating engine is working harder than normal and at an unusually low airspeed, which can cause overheating; so watch the oil and cylinder head temperatures.

Such a comparison will also help you form a realistic expectation of climb performance, if you examine where your aircraft fits into the "power loading" (pounds per horsepower) spectrum. Although aerodynamics, including wing area, aerofoil and drag also play a part, there is a close correlation between power loading and the engine-out accident rate, indicating that the more critical the engine-out performance, the more probable is an accident in the


Paul Phelan

# Transport category performance

THE UNCERTAINTY THAT SURROUNDS an engine failure in a single-engine or twin-engine light aeroplane is an unacceptable risk for the thousands of people that constitute the "travelling public" in large airline aircraft. Fortunately for them, the increased power made available by turbine engines – and the improvements in aircraft design since the 1950s – have made it possible to achieve a safe outcome following an engine failure during take-off or subsequent stage of flight.

The idea that an engine failure at any stage can result in a safe outcome relates to the concept of "assured performance". However, the assurance of achieving this safe outcome in a particular aircraft on a given day relies on 2 issues: the certification standard, and the limitations that must be observed when operating the aircraft (such as weight), so that it can comply with the certification standard.

Firstly, the aircraft type must be certificated as satisfying specific performance requirements in the event of an engine failure. In Australia, for aircraft originally designed and certificated in the United States, these requirements are contained in Civil Aviation Order (CAO) 101.6, titled "Airworthiness Certification Requirements – Imported Turbine Aeroplanes Above 5700kg Designed to CAR and FAR". In this CAO certain take-off performance standards are specified which must be demonstrated before an aircraft type can be issued with an Australian type certificate. The title of this CAO recognises that many aircraft in this category are of American origin or will, in the early stages of operation, gain certification in the US before operating in Australia. Although considered an airworthiness CAO , these requirements are essential background reading for the transport category pilot.

The second issue that must be addressed to achieve "assured performance" relates to the operating parameters of the aircraft on the day to permit compliance with the standard. It is pointless certificating an aircraft to achieve the standard if on the day it is operated at greater weight, altitude or temperature than that which will allow the standard to be achieved. These considerations are clearly the responsibility of the operating crew, and are specified in CAO 20.7.1B, "Aeroplane Weight and Performance Limitations – Aeroplanes Above 5700 kg – All Operations (Turbine and Piston – Engined)."

**Take-off phase:** When thinking of the performance problem following an engine failure, most of us would initially be concerned with the take-off phase, since this is likely to be the most critical. While CAO 20.7.1B specifies limitations that relate to take-off performance, the order also includes limitations that relate to landing and approach performance and route distance limitations. For example, a twin-engine turbine aircraft to which this CAO applies – anything from a Citation to a Boeing B767 – that has suffered an engine failure and is making an approach to land, must be operated so that in the event of a single-engine go-round, it can initially climb at a gradient of not less than 2.1 per cent.

Take-off limitations specified in this operational order cover a wide range of stages following an engine failure; however, the point at which the engine is considered to have failed is common to all stages. This common point in the take-off roll is known as V1, or decision speed, and is the most critical point because the aircraft has accelerated to a high speed but is not quite airborne.

The concept of "assured performance" means that an aircraft can either be stopped on the runway following an engine failure or can climb away safely depending on the speed at which the engine fails and is recognised as having failed. The point that divides these two options is V1. Providing the failure can be recognised by this point, the pilot can decide to abort the take-off safely. A failure that is recognised even 1 knot after V1 must be continued. The limitations specified in CAO 20.7.1B detail the performance gradients that must be achieved at the earliest stages of take-off with the landing gear down through the acceleration and "clean-up" stages right up to the stage where the aeroplane is considered to be in an "en-route climb". The order also specifies obstacle clearance requirements throughout these stages.

A knowledge of required standards is a must, and is usually part of a licence, rating or endorsement exam. However, for the thinking aviator, an understanding of background issues and theory can provide the necessary "edge" that is useful when the unexpected happens.

Watch out for a more detailed article on transport category performance in a following issue of *Flight Safety Australia*.

**“The average light twin at MTOW requires almost half its total available power to maintain level flight, and more in the take-off configuration, leaving very little in reserve to provide a positive climb ...”**

engine-out case.

The accompanying table provides the power loadings of most light piston twins in current service in Australia. A low value of power loading indicates a relatively higher ratio of engine power to weight, compared to a high value of power loading. In general, a low figure will provide better performance than a high figure, notwithstanding the effects of total drag. It should be noted that these data deal with individual models, and figures for some variants of a model are not included. As the table shows, some types have differing MTOWs for VFR and IFR operations; the reduced IFR weight being the weight at which the aircraft can maintain a 1 per cent climb at 5,000ft with the critical engine inoperative.

**Advanced:** Included in the “light twin” category are some pretty advanced aeroplanes, such as some of the turboprops in current use, which are not certificated in the transport category, and have no predicted performance until the aircraft is climbing with the gear retracted. In most cases, an engine failure in one of these aircraft will not be as serious as a failure as a failure in a light twin piston aeroplane.

Aircraft like the Twin Otter, Bandeirante, Super Kingair and the earlier Metros, operating in regular public transport (RPT) operations in Australia, must have the ability to survive an engine failure on take-off, but only once the propeller of the failed engine has been feathered and the undercarriage has been retracted.

With the gear down or the propeller unfeathered and windmilling, it’s highly likely that they won’t be able to maintain height until the pilot has identified the failed engine, feathered the propeller, and retracted the undercarriage. So there’s a window for 20 seconds or so from a fairly high speed near rotation, to the point where the undercarriage is retracted.

It’s then a question of how high the aeroplane is when the engine fails and its take-off weight, as to whether the pilot is able to climb away from the engine failure.

The provision of autofeather is a popular addition to aircraft in that category, as US Regulations for aircraft with 10 passenger seats do not allow credit for the pilot feathering the propeller following an engine failure after take-off. Without autofeather, the one-engine-inoperative performance of these aircraft as shown in FAA approved documents is derived with a propeller windmilling.

Apart from aerodynamic considerations, climb performance at a particular weight and temperature – on one or more engines – is directly related to the power available in excess of what is required to maintain level flight. The average light twin at MTOW requires almost half its total available power to maintain level flight, and considerably more in the take-off configuration. This leaves very little in reserve to provide a positive climb, and in many cases will be insufficient to maintain level flight.

In a typical light twin, as any instructor conducting conversion training will be careful to point out, engine-out performance is not just halved, it is reduced by 80 per cent or more as available graphs show; and the harsh reality is that in a critical situation, there are a large number of light twins which may not be able to climb at all.

As a US Federal Aviation Administration document once pointed out: “There is nothing in the FAR certification of light multi-engine aircraft with nine or fewer passenger seats which says they must fly (maintain altitude) while in the take-off configuration and with an engine inoperative”.

In fact, many of the light twins are not required to do this with one engine inoperative in any configuration, even at sea level. With regard to performance (but not controllability) in the take-off or landing configuration, the light twin is, in concept, merely a single-engined aircraft with its

## Power loadings of most light twins on the Australian register

| TYPE | TOTAL AVBL. POWER (HP) | MTOW (KG) | POWER LOADING (KG/HP) |
|---|---|---|---|
| Beech Duke 60 | 760 | 3,073 | 4.04 |
| Cessna 310 | 570 | 2,495 | 4.38 |
| Cessna 340 | 620 | 2,717 | 4.38 |
| Piper Seneca 1 (restricted IFR weight) | 400 | 1,760 | 4.40 |
| Beech Baron 55 | 520 | 2,313 | 4.45 |
| Cessna 421 | 750 | 3,379 | 4.51 |
| Piper Chieftain | 700 | 3,175 | 4.54 |
| Cessna 303 | 500 | 2,279 | 4.56 |
| Piper Aztec (restricted IFR weight) | 500 | 2,313 | 4.63 |
| Piper Aerostar | 580 | 2,722 | 4.69 |
| Piper Aztec (VFR) | 500 | 2,359 | 4.72 |
| Cessna 402B | 600 | 2,858 | 4.76 |
| Piper Seneca 1 (VFR) | 400 | 1,910 | 4.78 |
| Cessna 402C | 650 | 3,107 | 4.78 |
| Beech Duchess 76 (restricted IFR weight) | 360 | 1,723 | 4.79 |
| BN-2A-20 Islander (restricted IFR weight) | 600 | 2,889 | 4.82 |
| Beech Duchess 76 | 360 | 1,769 | 4.91 |
| Cessna 414 | 620 | 3,062 | 4.94 |
| Piper Seminole | 360 | 1,780 | 4.94 |
| BN-2A-2 Islander (restricted IFR weight) | 520 | 2,575 | 4.95 |
| Partenavia P-68 | 400 | 1,990 | 4.98 |
| Beech 18 | 900 | 4,491 | 4.99 |
| BN-2A-20 Islander (VFR only) | 600 | 2,994 | 4.99 |
| Cessna 337 | 420 | 2,100 | 5.00 |
| Beagle 206 | 680 | 3,402 | 5.00 |
| Piper Twin Comanche (restricted IFR weight) | 320 | 1,615 | 5.05 |
| Beech Queenair A-80 | 760 | 3,856 | 5.07 |
| Cessna 404 Titan | 750 | 3,810 | 5.08 |
| BN-2A-2 (VFR only) | 520 | 2,720 | 5.23 |
| Gulfstream GA-7 (restricted IFR weight) | 320 | 1,675 | 5.23 |
| Piper Twin Comanche (VFR only) | 320 | 1,690 | 5.28 |
| Rockwell Shrike Commander (USA certification weight) | 580 | 3,062 | 5.28 |
| Gulfstream GA-7 (VFR only) | 320 | 1,724 | 5.39 |
| Rockwell Shrike Commander (Aust. restricted IFR weight) | 580 | 3,243 | 5.59 |
| Rockwell Shrike Commander (Aust. VFR weight) | 580 | 3,357 | 5.79 |

power divided into two or more individual packages."

The safety advantages of flying at a lower weight are quickly obvious to anybody who takes the trouble to study the manufacturer's data.

As an example, the Piper Aztec D's performance graphs show a 240ft/min climb at sea level at MTOW (2,359kg). At just 1,000ft above sea level, climb rate drops to 200ft/min, and reaches zero at 6,000ft. But at 1814kg, climb rate increases to 625ft/min, and the aircraft is still climbing at 200ft/min passing through 9,000ft. And be aware that on a 38°C (100°F) day, the density altitude is increased by over 2,000ft, meaning the engine-out performance of any light twin will be seriously degraded on any hot day.

Those figures mean you can considerably enhance your safety margins by not carrying round trip fuel when you don't have to, or by reducing unnecessary load in other ways. They also point to the wisdom of using all available information to make yourself aware of what single-engine performance you can really expect, and of seriously contemplating the option, in some circumstances, of a forced landing as an alternative to attempting continued flight.

**Moment of truth:** That, and being failure-conscious as airline pilots are trained to be, may one day be the difference between a good and a bad outcome.

The moment of truth comes when an engine does fail in your light twin. It is usually quite sudden, and commonly occurs when the engine is developing high power or at the first power reduction after take-off. Will you automatically slip into the "aviate, navigate, communicate mode"? Will your aeroplane have been flying at the best speed for the configuration, and do you really have a grasp of expected performance for the circumstances?

Will you have mentally rehearsed your "energy management" actions until they have become automatic? Will one of your first actions be to pin the airspeed to the blue line, correct the yaw, and trim? Will you automatically go through the sequence of actions to identify and confirm the failed engine? Will you calmly reach the correct decision, having (if there is time) conducted all your emergency checklist procedures?

The most dangerous trap for any light twin pilot is blind acceptance of the implied promise that the second engine will always get you out of trouble.

---

*Paul Phelan is a freelance aviation writer with 40 years flying experience in Australia.*