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Aviation Safety Digest

Contents

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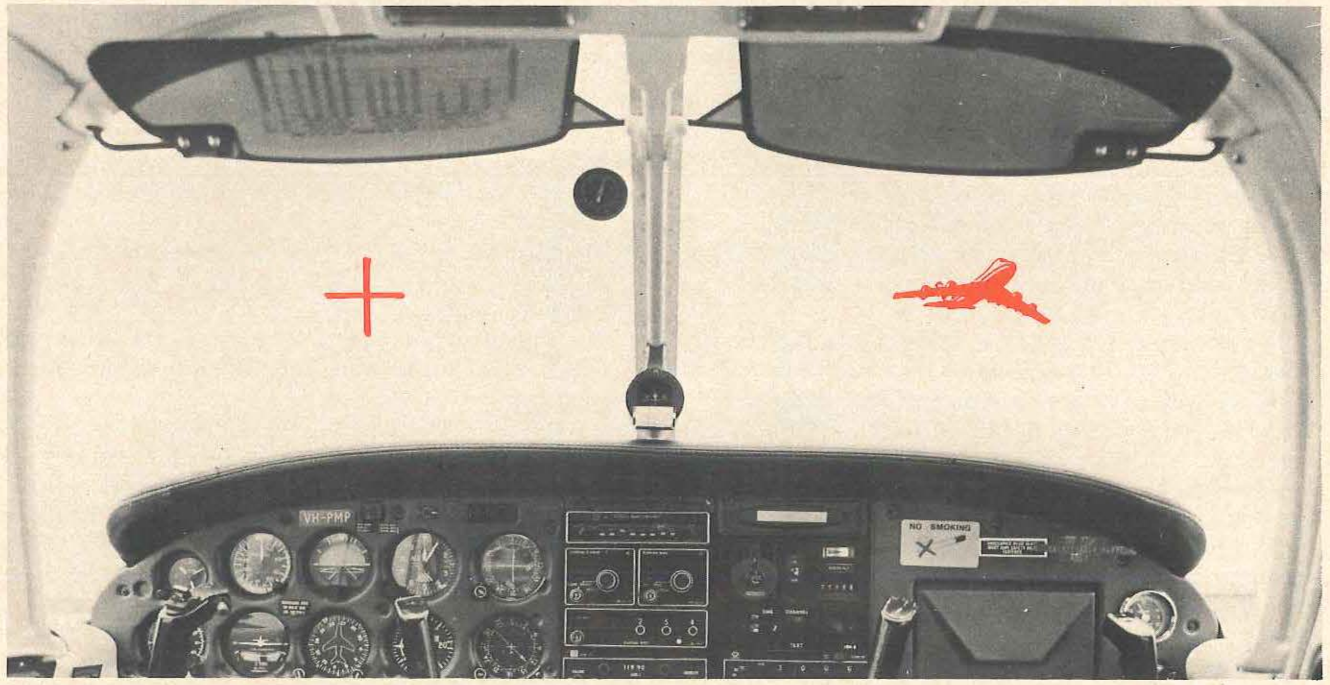
Front cover
BN2 Islander at Marawaka, PNG
Back cover
Cessna 185 at Lowai, PNG
Photographs courtesy of Mr G. Tait, Co-ordinated Air Services, Lae, PNG

Vision 1 — the blind spot

In aviation today, in spite of sophisticated air traffic control and navigation systems, the see-and-be-seen concept is still a most important element in collision avoidance. To make the most of this concept, we should know our sight limitations. This is the first of a series of articles concerning the physiological, psychological and environmental factors that affect visual efficiency.



One little known limitation of the human eyeball is the blind spot where light strikes the optic nerve. In most eyeballs this blind spot is about 30 degrees right of centre, looking straight ahead. With both eyes open and vision unobstructed by objects, the blind spots of each eye are cancelled by the peripheral vision of the opposite eye. The brain combines the image and the blind spot disappears.

But what happens when peripheral vision from the opposite eye is obstructed by an object such as a windshield centrepost? Now the brain cannot fill in the image. How large is the void? It's about a one-and-a-half degree cone diverging from the optic nerve. Under some conditions it could block instruments from view and will blank out a 707 two kilometres away. A 747 will disappear three kilometres away.

You can find your blind spot on the picture above. Hold the picture at arms length with both eyes open, focusing on the cross on the left windshield. Then bring the picture in until it is almost touching your face. With both eyes open you should not lose sight of the 747 in the right windshield. Now close your left eye and try it again. Keep your right eye focused on the cross as you bring the picture in towards your face. The 747 will disappear, then reappear as you draw the picture closer.

When your blind spot limitation is combined with empty field myopia (the tendency of the eye to focus at about six metres when there is nothing to focus on), you can really appreciate your visual limitations even under CAVOK conditions.

The solution to this problem, a natural phenomenon common to everyone, is to learn how to use your eyes in an efficient scan and overcome vision blockages caused by the aircraft structure.

How to scan

The best way to start is by getting rid of bad habits. Naturally, not looking out at all is the poorest scan technique, but glancing out at intervals of five minutes or so is also poor when you remember that it takes only seconds for a disaster to happen.

Glancing out and giving it the old once-around without stopping to focus on anything is practically useless; so is staring out into one spot for long periods of time.

So much for the bad habits. Learn how to scan properly by knowing where to concentrate your search.

In normal flight, you can generally avoid the threat of an in-flight collision by scanning an area 60 degrees to the left and to the right of your central vision area. This doesn't mean you should forget the rest of the area you can see from your side windows every few scans. Horizontally, the statistics say, you will be safe if you scan 10 degrees up and down from your flight vector. This will allow you to spot any aircraft that is at an altitude that might prove hazardous to your own flight path, whether it's level with you, below and climbing, or above and descending.

In the circuit area especially, clear yourself before every turn, and always watch for traffic making an improper entry into the circuit. On descent and climb-out, make gentle S-turns to see if anyone is in your way. Make clearing turns, too, before attempting any manoeuvres ●

Fuel consumption and the mixture control

During the preparation of two articles for *Aviation Safety Digest 103* ('Take notice of empty fuel gauges' and 'The last gasp') fifty reports of recent accidents and incidents which involved loss of power as a result of fuel exhaustion were analysed.

Three factors involving the pilot showed up time and again — inadequate knowledge of the aircraft's fuel system, failure to physically check the tank contents before departure and an over-optimistic idea of fuel consumption rates at the engine settings being used.

In many cases the inadequate knowledge of the fuel system took the form of confusion between Imperial and U.S. gallons in such areas as tank capacity, usable fuel, gauge calibration and fuel consumption graphs and tables.

The next in the trio of pilot factors — no physical check of the tank contents before flight — needs little comment. The gauge readings, the previous pilot's estimate, or even the most sophisticated calculation based on previous flight times is no substitute for looking in the tanks. This piece of wisdom is proven over and over again — unfortunately, too often the hard way — and the number of experienced and conscientious pilots who have fallen for the trap suggests that no one is immune.

The use of over-optimistic fuel consumption rates in flight planning apparently results from a failure to appreciate that rates shown in the Owner's Manual or Pilot's Operating Handbook are valid only if the mixture is leaned in accordance with recommended procedures. Furthermore, there is also a lack of appreciation of the magnitude of the fuel penalty resulting from incomplete leaning or omitting to lean the mixture during cruise. An old friend, the misconception that the mixture should not be leaned during cruise below 5000 feet, also showed up several times.

Engine operation with the mixture fully rich or only partially leaned during cruise is unlikely to cause any serious harm although there have been cases of an unusual form of exhaust valve erosion leading to failure, which have been attributed to the effects of an over-rich mixture. However, operation with an unnecessarily rich mixture is at best untidy and the fuel consumption penalty may be very high indeed.

In many cases a pilot's reluctance to lean out to maximum power seems to be caused by concern for the engine and this in turn is the result of the misconception that, when leaned in this way, the mixture is weaker than normal. As the following article from the *FAA General Aviation News* points out, leaning to maximum power is merely correcting an over-rich mixture which results from the reduced air density at altitude. The article is highly recommended as a clear explanation of the principles involved. Before going on, however, try this quiz for the aircraft you fly. Refer to the aircraft Flight Manual, Owner's Manual, or Pilot's Operating Handbook to verify your answers.

— What is the capacity of the fuel tanks?
— Is this in Imperial or U.S. gallons?
— What is the usable fuel?
— Are the fuel gauges calibrated in Imperial or U.S. gallons?
— What are the conversion factors — litres to Imperial gallons, litres to U.S. gallons, U.S. gallons to Imperial gallons?
— What is the maximum gauge error as shown by the fuel gauge calibration card and where does this occur?
— What does each division on the gauges represent? One quarter tank, one fifth, some other quantity?
— What cruise fuel consumption rate would you expect at 3000 feet:
  leaned for maximum power?
  leaned for maximum range?
  with the mixture control in full rich?

As an interesting, instructive and highly valuable exercise if you have not already done so, at the next suitable opportunity carry out an accurate check of the actual overall fuel consumption achieved using your normal power settings and leaning technique. You may be surprised.

Acknowledgement is given to the U.S. Federal Aviation Agency for the following article adapted from the *General Aviation News*.

The engine doctor and the case of the vanishing fuel

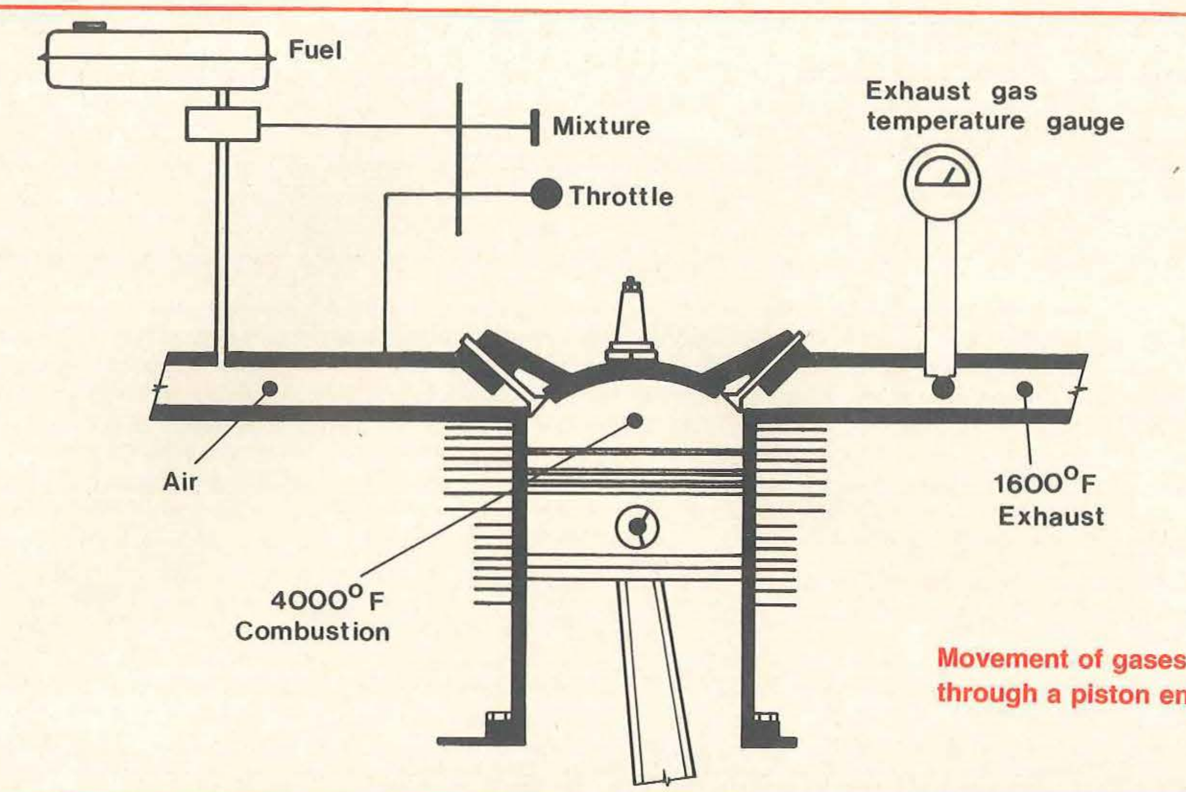
Pilot: Doctor, I've been referred to you for some advice about the aircraft I fly. I'm not getting anything like the range I should and the fuel consumption varies so much I don't know what to plan on. I make regular interstate trips and for the three hours flight I might use from 20 to 30 gallons of fuel. I hope it doesn't mean the engine is packing up — it's only done 800 hours.

Doctor: Let me get a little history. Has the fuel consumption always been erratic or has it just started?

Pilot: It's always been a little unpredictable but it seems worse over the last few months since I moved east and began making these regular interstate trips. It's only about 1100 km round trip and the book says I should get about 1400 km on a full tank at 75 per cent power, but Doc, if I don't refuel, I get home with the tanks almost dry.

Doctor: Hmmm. Sounds like a check-up is in order. Might not be serious, but then again . . . How does it run?

Pilot: It runs smooth — except when I fly over the mountains, and everybody knows aeroplanes always go into 'automatic rough' over water and mountains, so that's probably my imagination. As for a check-up, that was the first thing I thought of, so I had the hundred hourly done early, just to be sure. It all checked out okay. Plugs had a little lead on them but they cleaned up good. The LAME said there was nothing wrong that could affect the fuel consumption — nothing wrong at all. I even wondered if I was getting bad fuel — too low octane or something — so I asked around, but nobody else admitted to having the same problems. It worries me because I don't feel comfortable in a sick aeroplane. Can you suggest any special tests?



Movement of gases through a piston engine

Doctor: Maybe later — but first I want to examine your method of operation, if you don't mind.

Pilot: Oh, come on, Doc. I've got several hundred hours and never had a problem before. Ask the training school where I learned to fly — I soloed in six hours. Never bent anything, never had an accident — not even an incident. And I had no trouble transitioning to this aircraft, even if I do say so myself.

Doctor: I'm not questioning your flying ability, just wondering about your procedures. For example, what power settings do you use en route? And what about your altitude profile?

Pilot: I always cruise at about 70 per cent power, even though they say it's okay at 75 per cent — I like to be nice to my engine. I use 23 and 23 (2300 rpm, 23 inches of manifold pressure) most of the time. And the altitudes — they don't vary much either. I usually keep below 5000 until the Divide and then get up to about 6000 if the weather is clear. Once in a while, if it's early enough in the day so the air is smooth, I'll go up and over the mountains, that takes about 8000 feet. That's funny too! Instead of taking less gas to fly higher, I generally use more.

Doctor: I see. Now tell me, how do you make these altitude changes — by 'stair stepping' at fixed points?

Pilot: Well, no, just a gradual steady climb if I'm outside the CTA.

Doctor: Aha! And what about the mixture — do you make frequent adjustments?

Pilot: Not when I'm climbing, of course. I always lean when I get up to my maximum altitude. Of course, I always run full rich in a climb, or cruising below 5000, like you're supposed to.

Doctor: What makes you think you're not supposed to lean during cruise below 5000 feet?

Pilot: My instructor taught me that years ago, when I first learned to fly.

Doctor: I am afraid that is a very much misunderstood instruction. 'Never lean below five' is good advice when referring to take-off or climb power, certainly. But nowadays, at least, the engine manufacturers are telling you that with a normally aspirated engine at cruise power — which can be anywhere from 55 to 75 per cent of full power — you should adjust the mixture for any significant change in altitude or power setting. This saves fuel and keeps the engine running cleaner.

Pilot: At any altitude? Even at 2000 or 3000 feet?

Doctor: I've done it at 1000 feet and got improved performance. Why not?

Pilot: I heard you could get detonation . . .

Doctor: Not if you follow the manufacturer's instructions. Know your power settings — that's the key — they are all in the Pilot's Operating Handbook. Be sure the rpm are where they belong — and the manifold pressure, with a constant speed propeller like yours. In any case, if you climb steadily for most of the trip, without leaning en route, you can expect to waste a ton of fuel. You might be able to save about ten per cent out of a full tank by going to 8000 feet early, leaning the mixture properly, and cruising at that altitude.

Pilot: You don't say?

Doctor: I do. Incidently, when your old instructor cautioned you about never leaning below 'five' was he talking about density altitude or MSL?

Pilot: I don't remember. MSL I think. Does it make any difference?

Doctor: Considerable. For example, you might be flying out of an aerodrome at nearly 3000 feet this summer when the temperatures are around 35°C. That could give you a density altitude of over 6000 feet, which means that your engine is very likely to be running a little rough or giving you less than normal power if your mixture is at full rich on take-off, and while you are climbing.

Pilot: I never heard of taking off or climbing at less than full rich.

Doctor: You are hearing it now. Lycoming, who makes your engine, recommends that before taking off from any airport where the altitude is above 5000 feet density altitude, you lean at maximum rpm to the point where the engine runs smoothest — or by reference to the fuel flow meter if you have one. Naturally this does not apply to turbo-charged or supercharged engines, which always are on full rich at take-off.

Pilot: Naturally.

Doctor: Now suppose you describe for me your leaning procedure.

Pilot: Standard procedure, Doc. Ease the mixture control knob back until the engine gets a little rough, then push it in until it gets smooth. Tell you the truth, I get edgy when the engine even acts like it is going to run rough, so I usually stop leaning just short of that point.

Doctor: Oho! I suspect we have uncovered another root of your problem. With your tried and true method of leaning you are probably in the habit of feeding your little bird an overly rich diet, which leads to an inefficient performance and perhaps some other complications which have not yet surfaced.

Pilot: I still think it's the fuel. I never had any trouble before I came east.

Doctor: Perhaps. But I think your problems simply became more prominent here because we have higher and more varying terrain, which calls for more frequent and accurate mixture adjustment. Stopping short of a distinct engine response makes it impossible to lean accurately, especially without cylinder temperature or EGT gauges. What you experienced as 'automatic rough' over the mountains was probably the result of an overly rich mixture. No telling how much unburnt fuel you are blowing out of your exhaust. Do you know what the difference is in fuel consumption, at cruise, between full rich and optimum leaning?

Pilot: A few miles per gallon, I guess.

Doctor: I've heard reports varying from 15 to 25 per cent. Lycoming, for example, says that their higher horsepower engines use about three and a half gallons more per hour without leaning. They say that in a typical installation that will cost you one hour of flight time from a full tank.

Pilot: That much? That is considerable. But I still hate the idea of leaning till I get a rough engine or a bunch of detonation.

Doctor: I think you are unduly worried because the word 'leaning' has several different meanings. Let's back off a little and consider the basic situation. You know that your engine burns air and fuel in a proportion of approximately 15 to 1, by weight. When we achieve the optimum mixture we get what is known as a chemically correct combustion — or a clean burn. Virtually all of the oxygen and fuel are consumed, and all of the available energy is released. For any given engine this ideal proportion is the same at any altitude. However, with increases in altitude the density of the air is reduced, and the proportion of fuel is enriched. That produces an overly rich (or chemically incorrect) mixture and eventually a loss of power. We can compensate in one of two ways; by supercharging or turbocharging the engine — which compresses the air, so that the proper mixture is automatically maintained for us — or by what is popularly known as 'leaning'.

Now, leaning in this sense simply means pulling back on the mixture knob to reduce the rate of fuel flow to the carburettor or the cylinders. You 'lean' during cruise to achieve the chemically correct combustion — no more. For your type of engine there is no point in achieving a 'lean mixture', that is to say, a less-than-ideal proportion of fuel. This could lead to some engine problems under certain circumstances.

Pilot: That's what bothers me about leaning to roughness, before smoothing it out.

Doctor: I don't think you can go wrong by following your Pilot's Operating Handbook, and that is exactly what it tells you to do. You see, with small engines, and with practically all carburettor-equipped engines, fuel distribution is never exactly even. One cylinder will usually reach its lean mixture limit before the others and start misfiring, which produces roughness. But this is not the same as detonation, and normally the engine will not stop. Even if it should, from overzealous leaning, pushing in slightly on the mixture control should restart it immediately.

Pilot: Why don't we want to have a chemically correct mixture on take-off or climb, then? Or do we?

Doctor: No, we do not. Because the chemically correct combustion achieves peak temperature for a given power setting — about 2200°C at maximum cruise power. At full power the temperatures would be far higher, about 3300°C, and this would damage the engine, so at higher-than-cruise power settings we always keep the mixture on the rich side of the ideal proportion — full rich, for take-off below 'five'. It also happens that you get maximum power slightly on the rich, or cooler, side of your chemically correct mixture. You can observe this on our chart.

Pilot: Do you mean, the leaner the mixture the hotter the burn?

Doctor: That is true, up to a point. Remember too, the unburnt fuel in a rich mixture serves to help cool the engine.

Pilot: Then why bother to lean the engine at take-off on higher altitudes?

Doctor: Because if you exceed the rich tolerance limit you lose power, which you may need for a safe take-off. You may also get misfiring and possibly fouling of the plugs. You should know what rpm to expect, and be alert if you see them falling off. Ease the mixture out until they come back to normal, and then ease it in slightly.

Pilot: It seems to me that there ought to be a more scientific way of doing it. Aren't there any gauges that will help?

Doctor: There are temperature gauges, and they do help, within certain limits. We'll get into that next time you come in. Meanwhile, I suggest you go out in your aeroplane and put a few of the ideas we discussed into practice. See if your fuel consumption doesn't go down. Next please ●

Low cloud, blind valley . . .

Safe operation of an aircraft under Instrument Flight Rules involves more than just the manipulation of the aircraft controls. It requires adequate pre-flight planning and preparation. When the non-instrument rated pilot of a Piper Comanche entered cloud on a Special VFR flight, the aircraft struck a mountain and the pilot was killed. Fortunately, his two passengers had left the aircraft when it landed earlier and had travelled to their destination by car.

The pilot was a middle-aged businessman who had been flying for 16 years and had accumulated over 3000 hours experience, of which more than 1600 hours had been flown in Comanche type aircraft. He held a private licence but because of colour blindness, he was not authorised to fly at night. Several years earlier, the pilot had successfully completed a flight test for a Class 4 (Day) instrument rating but before his licence could be suitably endorsed, the Department withdrew this class of rating. At the time of the accident, the pilot did not hold an instrument rating of any kind.

As part-owner of the aircraft, the pilot had equipped it with an ADF, a VOR and a DME, and had a transponder on order. A two-axis auto-pilot with 'heading hold' capability was also installed, and the aircraft was approved for Night VMC operations.

On the morning of the accident, the pilot submitted a VFR flight plan at Archerfield for a flight with two passengers to Bundaberg and return, at a nominated cruising altitude of 8500 feet for the northbound leg. Other aircraft in the area on IFR flights reported considerable periods in cloud while aircraft maintaining VFR had to fly at lower levels. Most were compelled to divert from track and at least two aircraft were forced to turn back before reaching their destination. Towards Bundaberg, however, conditions improved and it was fine when the Comanche arrived.

By early afternoon, the pilot and his passengers had completed their business and they boarded the aircraft for the return flight. After taking off from Bundaberg at about 1400 hours, the aircraft climbed to the planned cruising altitude of 7500 feet but, shortly afterwards, the pilot was advised by Flight Service that both Archerfield and Brisbane control zones were closed to VFR operations.

By now, the weather over the whole area had deteriorated. Around Brisbane, conditions were being influenced by an unstable south-easterly stream, which was causing rapid fluctuations in the weather with heavy showers and low cloud. Reaching Gympie, the pilot requested a Special VFR clearance through the Brisbane control zone to Archerfield at either 7500 feet or 1500 feet but the clearance was not granted and the pilot was told that the conditions at Archerfield were at the minima.

At that stage, the pilot decided to land at Maroochydore and await developments. He made no effort to find a break in the cloud cover for the descent but began a let-down in IMC, over-flying the Nambour VOR and then tracking to Maroochydore. The aircraft did not become visual until it was down to about 1500 feet over the sea and, after orbiting to await the passage of a rain shower, the aircraft landed at about 1500 hours.

Once on the ground, the pilot telephoned the Archerfield briefing office and asked about the current weather situation at Brisbane and Archerfield. He was told that both control zones had been closed to VFR operations for most of the afternoon and that no prospects were held for any substantial improvement in the weather. He also discussed transitting through the Amberley control zone, apparently with the intention of making a roundabout entry to Archerfield from the west via Kilcoy. After some discussion, the pilot then said he would fly to Redcliffe on the northern boundary of the Brisbane zone and further review the situation from there.

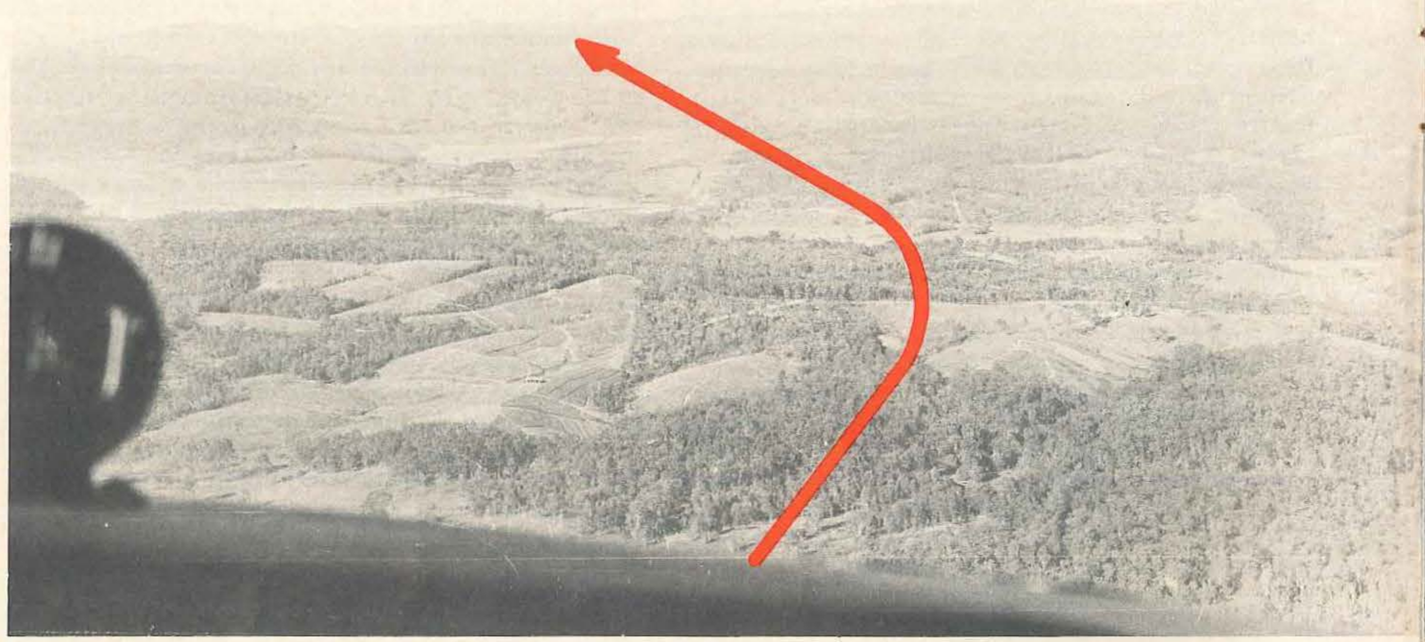
At 1626 hours, the aircraft took off from Maroochydore and while en route to Redcliffe, and before and after landing, the pilot again requested a Special VFR clearance to Archerfield, either via the lane of entry or through the Brisbane control zone, or alternatively a clearance with Brisbane Airport as the destination. Because of low cloud, restricted visibility and associated IFR traffic, none of these clearances were granted but it was agreed that the requests would be kept under review. As it happened, while the aircraft was on the ground at Redcliffe, a temporary improvement in the weather would have allowed ATC to consider Special VFR operations in the Brisbane control zone but attempts by Brisbane Flight Service to contact the aircraft were not successful.

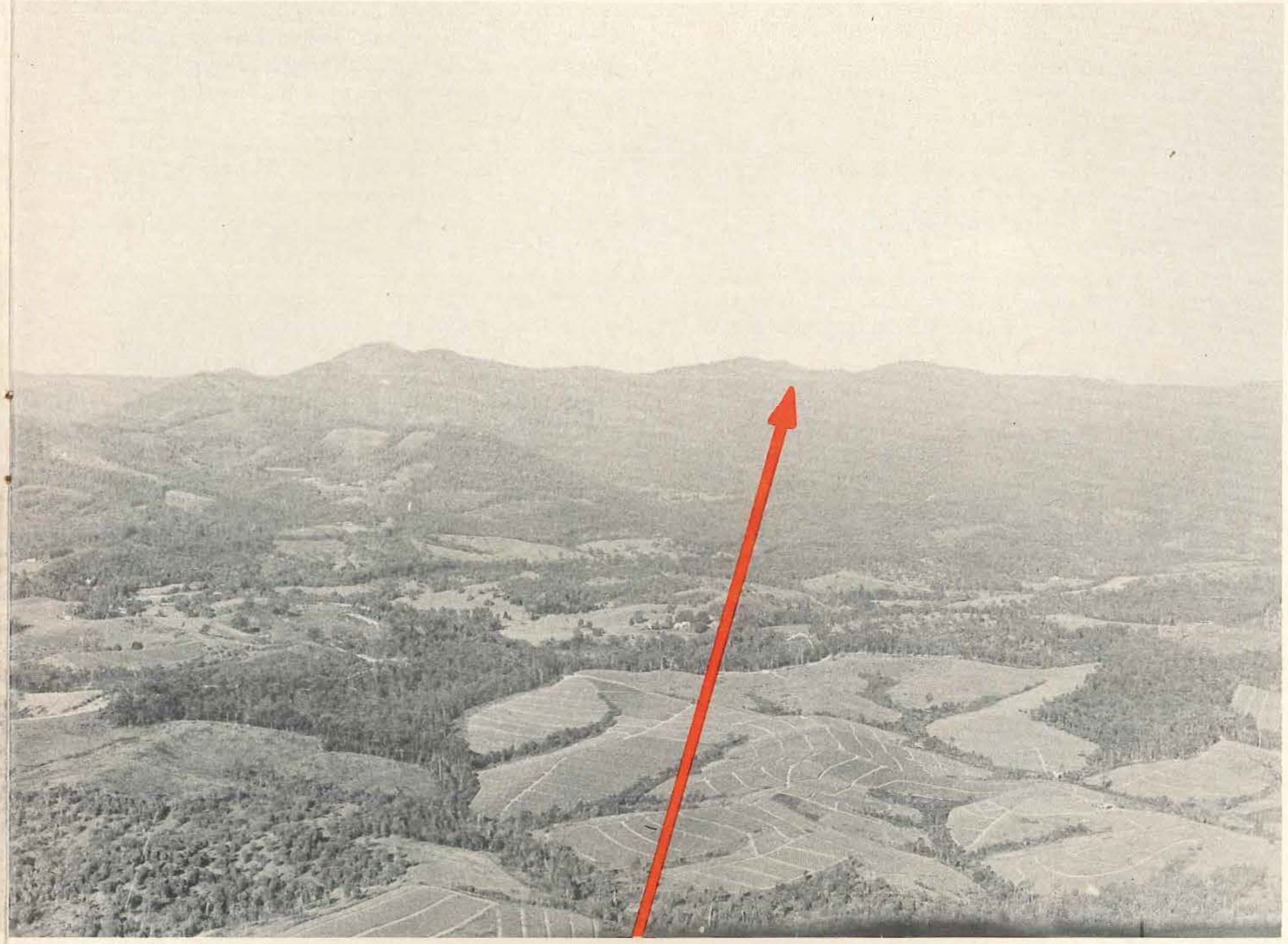
At this stage, the passengers decided to complete the rest of their journey by car but the pilot elected to stay with the aircraft, mentioning that there was still some daylight left and that the weather might improve. He telephoned a friend with a private airstrip to the south-west of Redcliffe and, after checking on the serviceability of the strip, arranged to fly there and, if necessary, stay the night. On departure from Redcliffe, the pilot again contacted Brisbane Flight Service and requested a Special VFR clearance to Archerfield through the lane of entry, but by now the weather had deteriorated again and the clearance could not be granted.

After landing at the private airstrip the pilot prepared to stay overnight, but then mentioned to his friend that he had to fly the next day and he was concerned that the strip, which had a natural surface, may become unserviceable if the rain continued during the night. Before securing the aircraft for the night, the pilot said he would make one last call to Archerfield and, at 1814 hours, he again telephoned the Archerfield briefing office. Once more he asked about the latest situation and requested a Special VFR clearance to enter the zone through the lane of entry.

At that stage, the cloud base at Archerfield was 1000 feet, the rain had eased and visibility towards the lane in the direction from which the aircraft would come was about 13 kilometres. It was stressed that, if the

Pilot's view of the northern entrance to the Archerfield lane of entry. The correct track is shown on the left; the probable flight path of the Comanche is on the right.





pilot lost no time in departing and if conditions remained the same, a Special VFR clearance for flight in the zone would be granted. Last light at Archerfield was 1843 hours and the pilot estimated the flight would take 13 minutes.

After telling his friend he might be back if the weather did not look suitable, the pilot returned to the aircraft. About 10 minutes later, it took off into the north but, instead of turning south-west towards the northern end of the lane of entry, it headed initially in a westerly direction, possibly to avoid a nearby rain shower. The pilot transmitted a departure time of 1822 hours, with an estimated time of arrival at Archerfield of 1835 hours. He was advised that he would be given a Special VFR clearance eight kilometres from the control zone boundary and his acknowledgement of this information was the last communication received from the aircraft.

Shortly afterwards, several witnesses in a valley about nine kilometres west of the lane of entry saw the Comanche flying in drizzle at a very low height beneath cloud. This valley heads in a south-westerly direction whereas the track through the lane of entry is to the south-east. Some distance along the narrowing valley, the aircraft began to climb and it disappeared into cloud.

When nothing more was heard from the aircraft, a Distress Phase was declared but it was not until four days later that the wreckage was finally discovered about 400 feet below the summit on the north face of Mt D'Aguilar, which rises steeply to 2550 feet. The aircraft had crashed in extremely rugged, inaccessible terrain, and the accident site was directly in line with the track of the aircraft when it was last seen from the ground.

It was readily apparent from the evidence of witnesses that the pilot, though not rated, occasionally operated the aircraft in instrument meteorological conditions. Passengers who had flown with the pilot earlier on the day of the accident reported that the aircraft had been operated in cloud and the pilot obviously considered himself competent in the use of all the radio navigation aids installed in the Comanche.

Although it was doubtful that the aircraft had been flown in cloud on the first leg of the flight northbound from Archerfield, there was no doubt at all about the return flight during the afternoon. The witnesses in the aircraft confirmed that the pilot descended in cloud at Maroochydore, using the Nambour aids. From 7500 feet down to a height of 1500 feet, the aircraft was in cloud and rain. At no time apparently, did the pilot contemplate returning to Maryborough or Bundaberg in VMC, or turning back until VMC was established and then proceeding visually beneath cloud to Maroochydore.

A further indication of the pilot's attitude to flying in cloud was his contemplation of a flight over Kilcoy and Amberley. With rain showers over the coast and hills, and with Brisbane and Archerfield both closed to VFR, it is inconceivable that any pilot could consider a VFR flight over that route as an alternative to flight along the coast. This flight did not eventuate of course but even to have contemplated it is indicative of this pilot's attitude that he was qualified but because of a technicality, unable to hold an instrument rating, and could therefore fly in IMC — albeit illegally — at any time. This seems to have given him an assurance of his capabilities far beyond that of the usual VFR pilot.

It appeared from his radio communications that the pilot continually painted a more optimistic picture of the weather conditions than other airspace users and observers on the ground. Even his telephone conversations suggested he was biased in his observations, and at one stage he was cautioned on his assessment of the weather.

At the time the aircraft took off from the private airstrip, a witness described the conditions as clear in the immediate vicinity of the strip with a general cloud base of eight oktas above 1500–2000 feet, five to six oktas at various levels down to 300–500 feet and traces of cloud between 150 and 200 feet along a nearby river. To the south, in the direction of Archerfield, and to the east the visibility was at least eight kilometres but to the north and west it was less than 1300 metres, and it was not possible to tell where the rain merged into the cloud base.

Although last light at Archerfield was 23 minutes after the aircraft took off, witnesses near the airstrip said the light faded quickly about 10 minutes after the Comanche departed. Quite apart from the other weather considerations, the pilot's decision to commence the flight in rapidly approaching darkness seems another indication of his attitude of being able to change to instrument flight at any time.

From the flight path of the aircraft subsequently established by ground witnesses, it seems certain that the pilot decided to fly around the shower near the entrance to the lane of entry and then turn south-east down the lane through the gap between the rain and the D'Aguilar range. For this reason he initially flew westward and then turned south-west in a sweep which the pilot probably thought would bring the aircraft into the lane.

It would appear that for some reason, the pilot flew too far west and turned up the wrong valley. Although the exact reason for his failure to turn is not definitely known, it is likely that in the prevailing conditions and at low level, he would have had difficulty in identifying visual reference points, particularly if diversions around showers were also required. The lane of entry and its northern approaches are difficult areas for map-reading, especially at low level. The countryside consists of undulating ground with a series of small valleys and timbered ridges lying across the lane. There is no clearly defined valley, road, river or railway line leading down the lane towards Archerfield. It has been estimated that the additional distance between the entrance to the lane and the point where the aircraft eventually turned up the valley would have been covered in about 45 seconds flying time.

Once the aircraft had entered the valley, it seems the pilot became aware of rising terrain on either side and put the aircraft into a climb. The pilot had once told one of the witnesses that if he was ever caught out by bad weather, he would climb out of it rather than try to regain visual contact beneath cloud. As the aircraft had struck the ridge directly in line with its last observed track, it is likely the pilot adopted this course of action. But the gorge at the end of the valley is very steep and it would seem that, once committed, the aircraft would have been unable to outclimb the D'Aguilar Mountain Range.

In a great many accidents that occur as the result of attempted visual flight in adverse weather conditions, the events leading up to the crash itself take place over a considerable time interval. Often the aircraft strikes some navigational difficulty or diverts around supposedly 'local' conditions for quite some time before it is finally trapped by the weather. This accident is unusual however, in that it happened only eight minutes after take-off on a flight with an expected duration of 13 minutes. The decision to attempt the flight was made in this case while the aircraft was safely on the ground, the weather which was to be encountered was clearly visible from the ground and the pilot knew the terrain to be crossed. He was aware of the failing light and that conditions had been fluctuating rapidly throughout the afternoon.

Though the pilot had persisted in his efforts to reach Archerfield during the whole of the afternoon he did not mention any pressing need to complete the flight that evening. Certainly, he had been concerned about the possibility of rain affecting the serviceability of his friend's airstrip, but at that stage he had the option of flying back to Redcliffe, only four minutes away, and leaving the aircraft there for the night. Earlier, when the aircraft was on the ground at Redcliffe, the pilot seemed quite resigned to the situation and the possibility that he might have to spend the night at his friend's place. He gave the impression that he might as well stay with the aircraft and see how the weather developed, without being concerned too much either way. Nevertheless, he did not leave the aircraft at Redcliffe and, when flying to the private airstrip, he continued to seek special clearances to reach Archerfield.

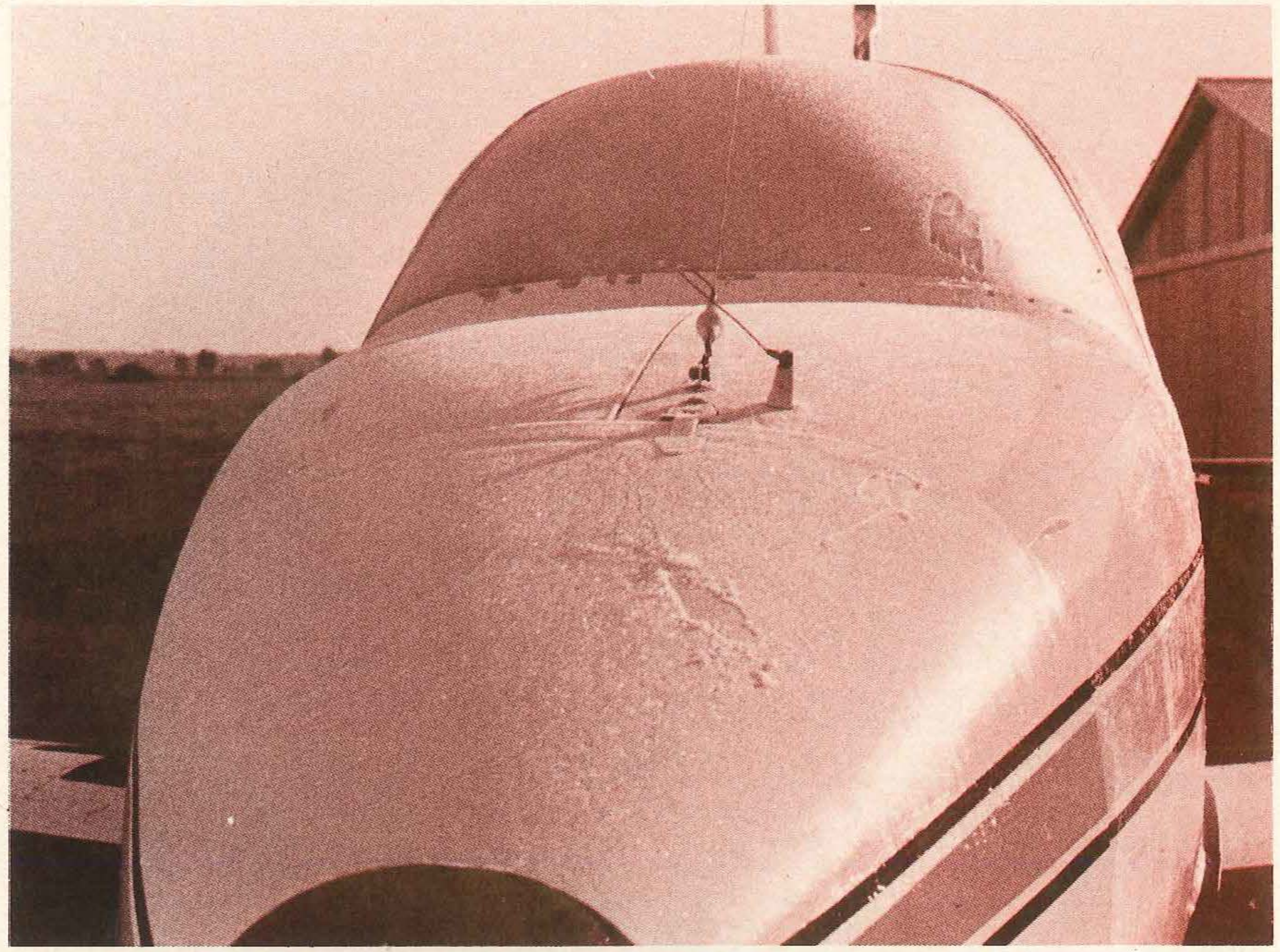
The pilot was aware that conditions suitable for 'Special VFR' existed in the lane of entry eight km from the boundary of the Archerfield control zone and obviously intended to stay visual below cloud and make a quick low-level flight to that point. Before taking off, the pilot had remarked to his friend that, if conditions were not suitable, he would be back. But a return to the private strip would only have been possible for a few minutes after departure because of the fading light, and though the pilot probably intended to remain below cloud, his 'way out' if he encountered any problems would not have been a return in VMC, but a climb in IMC.

The pilot did not seem in any way overawed by the task ahead of him but seems to have been supremely confident that, once the 'formality' of obtaining the Special VFR clearance eight km from the Archerfield control zone boundary had been met, his arrival was assured. Although he said he might return, it was not very likely he thought he would be back. It seems the pilot's confidence in his ability to fly on instruments was such that he believed he could extricate himself from any difficult situation if it became necessary.

On this occasion, by the time the pilot realised he was in difficulty, the aircraft was already in a position from which it could not outclimb the rising terrain in the distance available ●

Frost

It is not hard to imagine what a layer of frost like that in the photograph could do to the aerodynamics of an aircraft. Our picture was taken at Roma in Queensland on a clear July morning and shows the amount of frost that can form on the external surfaces of an aircraft in certain weather conditions — even in the 'Sunshine State'.



But the frost need not be as thick as this to create a serious hazard, as the pilot of a Cessna Agwagon discovered recently when he attempted an early morning take-off from an agricultural strip in south-eastern Queensland, with a thin layer of frost on the wings.

The pilot had commenced operations from the strip the previous afternoon and, when he had finished for the day, he refuelled the aircraft and left it parked in the open. The next morning was cold and cloudless, and there was no wind. Returning to the strip at about 0600 hours, the pilot carried out a daily inspection and found the aircraft covered by a thin layer of frost. He was aware of the hazards of attempting to operate aircraft with frost on the wings, but he considered on this occasion it was not thick enough to cause a problem. He started the engine and let it warm up while the loader driver prepared to load the aircraft.

While the engine was running, the pilot noticed the slipstream from the propeller had blown all moisture off the windscreen. He carried out his pre-take-off checks and, with the aircraft loaded to about 66 kg below the maximum permissible take-off weight, he lined-up for take-off. Opening the throttle wide, he checked the engine was delivering full power and, as the aircraft accelerated along the strip, the tail lifted normally.

At 65 knots, he tried to lift off but there was only a slight shuddering and the aircraft would not become airborne. He continued the take-off and, at a higher speed, the aircraft eventually left the ground but immediately struck a fence at the end of the strip. The pilot quickly closed the throttle and the aircraft landed heavily in a wheat crop in the next field. The left landing gear broke off, the left wing tip dug in and the aircraft somersaulted on to its back and came to rest inverted some 240 metres from the end of the strip. The pilot was not injured.

The pilot was very experienced in agricultural operations and had a total of about 12 500 flying hours. He had encountered frost on his aircraft before and his practice was to either hose it off or, if a hose was not available, to fly the empty aircraft once around the circuit.

On this occasion, the pilot saw that the frost on the wings was about three millimetres thick and he did not consider removing it because he believed a layer as thin as that would not be sufficient to cause any significant degradation in the aircraft's handling characteristics. The pilot was unaware, however, that it is not so much the thickness of the layer that creates the problem as its irregular surface. This roughness increases drag and causes early airflow separation over the wings. A higher airspeed is required to generate sufficient lift for take-off, and consequently a longer take-off distance is necessary. Had the pilot been mindful of these effects, he might have recognised the reduced performance sooner and either dumped the hopper load in order to clear the fence or abandoned the take-off and brought the aircraft to a stop — even if it involved a deliberate ground loop at low speed — with far less disastrous results.

The accident to the Agwagon provides a timely reminder of the hazards in neglecting even a thin coating of frost on an aircraft and shows that the problem is not confined to cooler climates but can occur in normally warmer areas given the right conditions.

Yet another aspect of the frost hazard was brought to our notice recently by the captain of a DC-9 which was being pre-flighted at Canberra for a scheduled early morning departure for Sydney. While carrying out his external inspection, the captain noticed areas of frost extending over about five square metres on the top surface of each wing. Deciding to have a closer look, he stood on a baggage barrow and discovered large areas of ice up to about three millimetres thick which were not visible from the ground. One of the cabin overwing emergency exits was then removed and a further check revealed what at first sight appeared to be water from melted frost on the inner section of the wing but on closer inspection turned out to be clear ice.

The captain said the outside air temperature at the time was zero degrees Celsius and there was some sunlight on the wings. It seemed to him the frost had melted in the weak sun and then run down the wing surface, which was still very cold, and re-frozen. The aircraft was delayed for 80 minutes while the upper surfaces of the wings and stabilizer were de-iced with alcohol.

During his pre-flight inspection, the captain recognised the frost patches as a potential hazard, and his persistence in following up the initial indications no doubt averted what may well have developed into a serious occurrence ●

Wings, wizards and wisdom

An old-head aviator tells how superior skill and cunning can be overcome by bad planning and bad judgment.

I stood in the grass near the runway watching the spot landing contest. The lightplane pilots were aiming for a line painted across the runway just beyond the numbers, and several had come fairly close. A red and white Cessna was now on downwind for his shot at winning the prize. The pilot pulled the throttle to idle and I watched his pattern towards the target. When he turned from base to final, he was obviously too high. He slowed the aeroplane by pulling the nose up and the descent angle steepened. It was still apparent that he was going to overshoot so he pulled the nose up even higher, violating everything sacred to safety. His genius for converting lift into a plummeting descent was outstanding. It appeared that he might at least come close to the target. He was low enough that I could see the set of his jaw and I imagined crosshairs on his glazed eyeballs as the plane dropped rapidly towards the mark.

The landing gear tried to cushion the crunch, but it spraddled with an indecent shedding of aluminium garments into a shameful heap. I ran to offer assistance, but found two healthy people, although the dazed pilot seemed a bit crestfallen. His disappointment was centred on missing the target, instead of the fact that he had just bent his aeroplane.

This incident is an example of poor judgment — the kind of situation caused by a pilot not properly ordering his priorities. When people are unable to place things into proper perspective they can become a hazard to themselves or others. They may be highly skilled, even extremely smart, but something happens to them that short-circuits their ability to see things as they really are. In a similar way, pilots are sometimes struck with moments of insanity that temporarily paralyse their judgment. You may be a wizard at the art of flying but if you can't put things in their proper perspective, you're probably heading for an accident.

We all acknowledge that safety has priority over most things. Why then, do low-priority items so often lead to an accident? The desire to get a contract signed over at Fogville, a compulsion to get home in spite of a strange-sounding engine and bad weather, or the temptation to show the boss you can descend lower than minimums and get him to that important meeting are low-priority reasons for flying. A conscientious pilot will not permit demands of such minor importance to compromise his basic desire to fly safely.

There is a tendency to equate the ability to make good decisions with some unrelated qualities such as IQ. I know some very smart people who were involved in flying stupidly, so it isn't mental voltage that determines the use of judgment.

Whether we are wizards or just ordinary folks though, our ability to make good decisions should improve with experience. As a young and inexperienced aviator, I impulsively blundered into more than one hair-raising adventure. Now, as I view the same situations through bifocals under thinning grey hair, I have insights that provide barriers against foolishness. I'm sure that frequent doses of substantial fright had much to do with changing my attitude towards flying. The most important change was my development of a more thoughtful attitude.

The cool head who does everything right when the serpents of disaster are coiled for a strike has probably conditioned his decisive powers through a thoughtful attitude. As a flight instructor, I try to pass on as much of my experience as possible to my students. We practise simulated emergencies that can be done with a reasonable margin of safety, but I can only carry those simulations so far. Beyond that line of safety I encourage pilots to think about potential hazards and emergencies and try to visualize what they would do — the thoughtful attitude. Flying is a thinking person's game. The unimaginative pilot is potentially dangerous because he can't visualize the results of his decisions.

Unfortunately, some employers fail to understand that a pilot needs plenty of time to think about everything relating to flying. The boss who expects a pilot to work too much at non-flying tasks is pouring sand into mental machinery that should be geared for the realm of flight. Ideally, a pilot should approach the aircraft with nothing on his mind but getting to his destination safely.

We have little difficulty, in a routine environment, keeping our minds working as they should; we perform all the normal cockpit duties with skill and efficiency. But when we are forced out of our usual pattern, we must be alert for deficiencies in our performance. Let's look at an example.

Once I was asked to fly a high-ranking foreign air force official from Burbank to Palmdale in a light twin-engine aircraft. I was told to show him extra courtesies and consideration. When I met him, he immediately informed me that he was a great pilot, and questioned my qualifications. I assured him I could not match his ability and changed the subject. After the run-up, I called the tower and was 'cleared on to hold'. As I swung on to the runway, Generalissimo Ego shoved both throttles to the wall and declared, 'I fly'.

I subdued my rage, forgot about the tower's instructions to hold, and tried to keep this maniac from busting the aeroplane. When we reached the intersection of the two runways, another aeroplane flew over the top of us and the tower reminded me that I was only cleared to hold.

Accidents are often the result of cockpit surprises that cause our thinking processes to quit functioning. These intruders take many forms: attitudes, pressures, emergencies, emotions — anything that's not part of the routine.

A major deficiency that often contributes to aircraft accidents is failing to take enough time for complete pre-flight planning. A dramatic personal example of how haste makes waste occurred at an airshow at the old Curtiss-Wright airport on Long Island.

Our airshow troupe had been pushing a front all the way across the country from California and we had frequent delays because of weather. I was first to arrive — about 15 minutes after showtime. The promoter started prodding me to get into the air. One of my acts consisted of a rocket-assisted take-off. The rocket bottle was already fastened to the belly of the 450-horsepower Stearman and all I had to do was hook up the ignition wire.

With everything connected and ready, I quickly taxied the biplane to the runway and, without a moment's hesitation, took off. When I felt control effectiveness, I detonated the rocket. The aeroplane jumped ahead with a tremendous surge and I jerked the Stearman into a vertical climb. Then, at about 200 feet, the engine quit — cold.

The rocket's location caused the aeroplane to arc towards the inverted position. I shoved the stick full forward but the reaction was too powerful to overcome. Suddenly the aeroplane snapped into a wild, inverted gyration and settled into the dense column of rocket smoke. With the nose now pointing towards the ground, the engine restarted. Using both rocket and recip. power, I regained control and pulled the aeroplane from the dive as details on the ground rushed sharply into focus. I fully expected to crash and, but for the grace of God, I would have.

The cause of this near disaster was my forgetting to turn on my all-attitude fuel system prior to take-off. When the stuntplane was pointed straight up, the gravity fuel system failed and the engine quit. Perhaps readers are not as fallible as I am — it's my nature to hurry. But when I'm around an aeroplane, I need the self-discipline to slow down — to protect myself from myself.

Some pilots seem to have an intuitive ability to sense trouble and avoid it. This intuition is probably nothing more than an appreciation of what's taking place around them. For example, while walking to the aeroplane on a hot day at a remote airport, you note the softness of the asphalt. Not a breath of air is stirring; the pressure altitude and the temperature are high. A look at the performance data shows that the runway is just long enough.

You fire up the turbines and watch the starting temps closely. It takes a bit more than normal power to taxi as the aeroplane rolls slowly on heavy, sticky tyres. The air conditioning ducts are fogging profusely and spitting snow.

With everything checked, you start a turn on to the runway and observe the windsock at the take-off end is hanging limp while the one at the other end is swinging wildly. You look at the hill about a mile off the departure end of the runway and observe dust spilling down the slope toward you. You shake your head and announce, 'We're going to wait a few minutes.'

'Why?' asks your co-pilot.

'Something tells me I should,' you answer.

Perhaps without realizing it, in a few moments you had evaluated many factors that could not be readily measured, such as pressure altitude, humidity, rolling friction, and wind shear. After waiting a few minutes both windsocks indicate about 15 knots of wind blowing down the runway. Now you take off safely.

Experience and training are the keys to developing judgment. Every mission and every aircraft can teach you something — if you remain alert enough to see it. Most of us avoid certain areas of flight and often we should do exactly that. There is a tendency, however, for us to establish too much of a buffer zone between what we consider hazardous and safe. This decreases our proficiency for handling situations which aren't routine. Training missions allow us to challenge our abilities — to make a *safe* mistake — and force our minds to work under pressure. Getting the most out of a training mission builds both skill and judgment.

An honest self-evaluation is very important, but difficult to develop. It's often harder to say, 'I'm not qualified to fly that mission,' than to bet your life by taking the flight. The adage that there are no old, bold pilots is not true, because I know some; but none lack humility.

When the next accident occurs, the next life is lost, it will be one of us. We will be intercepted by some circumstance that short-circuits our wizardry and causes us to perform as fools. Eighty-five per cent of all aircraft accidents are caused by human factors. So it seems obvious that we are potentially defective and need as much working in our favour as possible.

One of the reasons most of us choose to fly aeroplanes is because there is an element of risk involved that challenges us. Make no mistake about it, despite technological innovations and better aircraft performance, the risk and the challenge are still with us and will continue to be there in the future.

About the author

Mr Mason has a broad background of experience covering 44 years as a pilot and over 29 000 flying hours. He worked for Lockheed for 22 years as an engineering test pilot and was the first person to do aerobatics in a helicopter. He now owns and operates an aerobatic flying school in Santa Paula, California, U.S.A. ●

Wind shear in Australia

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Wind shear as an operational problem

Unexpected low level wind shear constitutes a significant hazard to aircraft during landing and take-off. It has been cited as a prime cause in the official reports of several recent aircraft accidents, and has attracted considerable attention throughout the aviation world.

Wind shear is defined as a change in wind speed and/or direction occurring in a relatively short distance. Such changes may occur with height (vertical wind shear) or lateral distance (horizontal wind shear). These conditions cause changes in airspeed and flight path with occasionally disastrous consequences.

When an aircraft is cruising, any wind-induced airspeed changes tend to be negated after a period by a corresponding aircraft inertial speed change. That speed change might follow a height change and the drag/thrust imbalance created by the original airspeed change. However, for aircraft at low level on approach to land, safety margins in height, speed and time are relatively small. If the wind change is rapid enough to exceed an aircraft's acceleration capacity, and is large enough to match its airspeed margin over the minimum approach speed for the given configuration, then a potential hazard exists.

With reference to Figure 1, for an aircraft making a stable approach on the required glidepath, if a rapid reduction in headwind is encountered then the initial effects are those of rapid reduction of airspeed and deviation below the glidepath i.e. an undershoot effect. This requires a thrust increase to regain airspeed and return to the glidepath. However, once re-stabilised with the reduced wind magnitude, the power setting will be less than that originally used before the wind shear encounter.

An aircraft taking off into the same wind structure will experience a rapid increase in airspeed and increased climb performance with deviation above the expected climb path.

Conversely, if an aircraft on approach encounters a rapid increase in headwind, as in Figure 2, then the initial effects are a rapid increase in airspeed and deviation above the glidepath, i.e. an overshoot effect, requiring reduction of power in order to return to the glidepath with the appropriate airspeed. A secondary hazard can arise if the aircraft has a high rate of descent, reduced power and decaying airspeed whilst close to the ground.

In addition to changes of wind flow in the horizontal plane, vertical wind flows contribute to wind shear effects; downdrafts from thunderstorms are an important example of this effect.

Accidents

Since 1970, several accident reports which cited wind shear or downdraft as causal factors have been reprinted in the *Aviation Safety Digest*. In most cases, nearby thunderstorms or intense rain cells were associated with the wind conditions. Visual difficulties (including the absence of VASI information) were frequently associated with the crash situation.

In several undershoot accidents at RANAS Nowra in the period 1958 to 1964, aircraft experienced a rapid increase in rate of descent late on approach to runway 26 during westerly winds. Terrain-induced downdraft and misleading visual cues were identified as causal factors. The problem has subsequently been relieved by a large earthworks programme which effectively extended the eastern end of the airfield plateau.

Meteorological factors and terrain effects

Several meteorological factors and the surrounding terrain can cause changes (speed and direction) in local winds at low level. These include:

— lee effects where the area in the lee of an obstruction contains waves, rotors, eddies or calm areas;

— contour-following effects where the wind tends to be deflected parallel to the ground surface resulting in downdrafts and updrafts as the air flows over plateaus, ridges and gullies;

— roughness effects where friction between a moving air mass and the earth's surface reduces the rate of flow in the lower layers of the atmosphere. The thickness of the layer affected depends upon wind speed, temperature lapse rate and surface roughness. Through that layer, the wind direction, as well as speed, will normally vary with height. The *gradient height*, defined as the height above ground of the top of the friction layer, varies from about 750 ft for smooth surfaces (such as open sea) to about 1500 ft for rough surfaces (such as large city centres).

Wind shears produced by terrain usually exist for appreciable periods without change and are therefore regarded as stable.

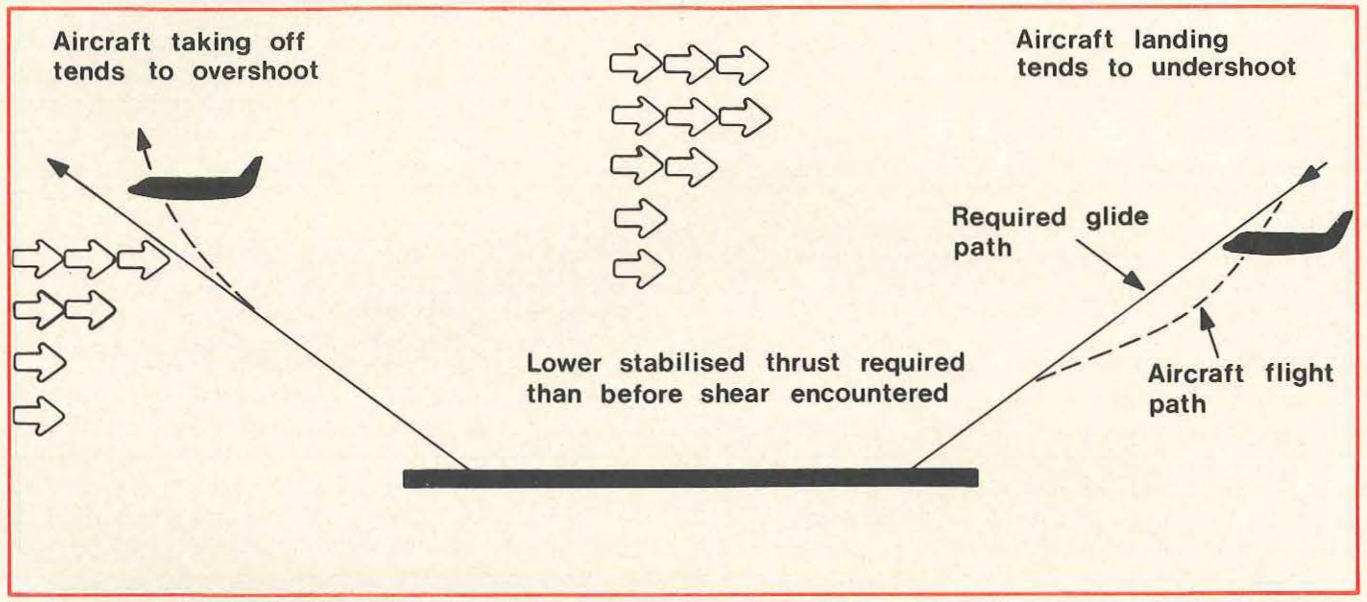
Other stable wind shear situations can occur when an area is affected by a low level jet stream, a marked temperature inversion or a sea breeze established against a moderate pressure gradient wind. In these cases, the airmass aloft can have a flow different from that of the lower air.

Transient wind shear situations may change over periods as short as a few seconds. They are usually associated with changing weather, especially frontal movement and storms.

The wind speed around a thunderstorm varies with both time and position. In the centre there may be strong updrafts and downdrafts, while in the surrounding air large vertical wind shears may be evident. A rapid increase in wind speed is characteristic of the first gust of an approaching storm. Within about 16 km of a thunderstorm, large fluctuations may occur in an aircraft's vertical and horizontal airspeed regardless of flightpath or ground speed.

With a cold front, as with thunderstorms, the associated wind will vary with both time and position. The passage of the front may be considered as a wedge of cold air which is undercutting warmer air. Some upwards motion of the warm air occurs before it turns to move horizontally away from the frontal line. Sudden temperature and pressure changes can be expected at the commencement of the passage, and heavy rain is often present. The most extreme wind changes in the leading gust line occur when the front is fast moving, or the temperature gradient is large. Hazardous wind shears can exist in the lower layers for up to one hour after the passage of the front.

Fig. 1. Head wind component increasing with altitude



Sensors

Ground-based systems

Close to an aerodrome, measurement of wind aloft by equipment on high towers is not practicable, so a remote technique is preferred. At present, the only routine measurements of conditions in the lower atmosphere are made with balloon flights, a few times a day at most, at major aerodromes. These measurements lack the time and spatial resolution for operational use as a wind shear indicator. At the Defence Research Centre, Salisbury (DRCS) in South Australia, an acoustic-sounding technique has been evaluated as a means of remote wind measurement. Using ground-based antennae and digital signal processing, the system can provide three dimensional wind data for the region 300–3000 ft vertically above the antennae. Some difficulties with ambient noise have been experienced and alternative sensing techniques have been reviewed. Other studies in acoustic sounding are progressing at RAAF Point Cook and Boulder, Colorado.

Another system of ground-based sensors has been used to detect gust fronts by measuring small jumps in temperature or pressure.

Airborne systems

It has been claimed that some aircraft-based sensors are useful in detecting wind shear. These include: (i) angle of attack instrumentation; (ii) the NASA total energy monitor system which displays the rate of change of the combined kinetic and potential energies of the aircraft; and (iii) the *Safe Flight* device which computes the rate of change of horizontal wind and the downdraft drift angle. All of these devices are aids to the recognition and management of a wind shear that the aircraft is currently encountering. They are not forewarning devices for that aircraft.

Questionnaire detail

Apparently, no systematic investigation had been made either in Australia or overseas about the wind shear experiences of aviation personnel. It was therefore expected that a questionnaire survey directed at Australian pilots and air traffic controllers (ATCs) would yield valuable information about the extent of any difficulties with wind shear, and could also provide guidance in the development of techniques for combating wind shear if these proved to be necessary or desirable. For reasons of expedience, the survey was restricted to military pilots and ATCs, civil regular public transport (RPT) pilots and DoT aerodrome controllers.

The survey was aimed at operators whose experience was relatively recent, and so an attempt was made to exclude persons who had not been flying or controlling air traffic during the preceding 12 months. Table 1 gives the numbers of eligible persons (i.e. those having recent experience) in each group, together with the chosen number of persons within each group to whom a questionnaire was dispatched.

	Eligible population	*Number sampled*	*Percentage*
Pilots			
Air Force	613	408	67
Army	95	95	100
Navy	65	65	100
RPT	1960	196	10
Air traffic controllers			
Air Force	233	158	67
Army	25	25	100
Navy	12	12	100
Dept of Transport	1000	76	8

Table 1

Where the sample size was less than 100 per cent, a technique for subject selection was required to ensure an even distribution of the sample throughout the parent group. Where possible, selection was arranged to give a representative cross section of experience.

The following subject areas were included in the survey:

— understanding of the effects of wind shear;
— understanding of the various definitions;
— reading in aviation journals about wind shear;
— cues for anticipation of wind shear;
— cues for recognition of effects of wind shear;
— approach strategy in various wind conditions;
— estimation of degree, location and frequency of wind shear conditions;
— susceptibility of different aircraft types to wind shear conditions; and
— opinions of the content and timing of various proposed warning messages.

Table 2 shows the numbers of questionnaire respondents in relation to the number of questionnaires dispatched, for each functional group.

	Questionnaires dispatched	*Questionnaires returned*	*Percentage*
Pilots			
Air Force	408	271	67
Army	95	65	68
Navy	65	33	51
RPT	196	93	47
Air traffic controllers			
Air Force	156	109	70
Army	25	17	68
Navy	12	8	67
Dept of Transport	76	56	74

Table 2

Most respondents appeared to react positively to the survey. More than half of those who answered and returned the questionnaire wrote a paragraph or more in the *general comments* space. Most gave written replies where invited and many expanded on the multi-choice answers as well.

Some respondents were clearly unfamiliar with wind shear problems. For them the survey served as an educational aid by implicit coverage of certain aspects, and as a catalyst for subsequent discussion with their colleagues.

Questionnaire findings

Frequency of wind problems

When asked to estimate the frequency of *dangerous conditions due to wind shear, wind gradient or downdrafts,* respondents produced widely differing answers. Some respondents commented that the word *dangerous* was subject to various interpretations.

Among ATCs, the controllers at Nowra (Navy), Perth (civil) and Jandakot (civil) selected the highest average frequencies of monthly to three monthly. The lowest frequencies of once in 3 to 10 years were produced by Adelaide controllers. The numbers of controllers at the various locations are however too small for statistical reliability on this aspect.

Many pilot respondents made no estimation at all. The number of non-zero answers is given in Table 3. The estimations pertain to the number of dangerous situations in the flying career of each respondent. For comparison, the questionnaire also sought similar figures for wake turbulence problems.

	Wind shear problem		*Wake turbulence problem*	
	Take-off	*Landing*	*Take-off*	*Landing*
Civilian pilots (93)	25	54	9	12
Military pilots (369)	92	189	100	164

Table 3

Civilian pilots were asked to estimate how often wind problems might cause each of them to induce a go-around on landing. Approximately half of the respondents gave a non-zero answer; this was nearly always less than five times per year.

In most respondent groups, the number of individuals who estimated the wind shear problem as greater than the wake turbulence problem exceeded those with the opposite opinion by a large ratio. In the case of Air Force pilots, however, this ratio was much smaller. Many of the respondents selecting wake turbulence as the greater problem made reference to formation flying.

Approximately half of the responding pilots described a condition of some wind difficulty, but many of these were surface problems (such as crosswinds and gustiness) or cruise problems (such as clear air turbulence and mountain waves at higher levels).

Of 143 accounts of low level wind difficulty, sufficient information was given with 131 to allow the following categorisation:

— vertical shear of horizontal wind	31 reports
— downdraft	47 reports
— shielding effects	12 reports
— frontal and thunderstorm	15 reports
— wake turbulence	26 reports

The wake turbulence incidents seemed to be the most hazardous.

Worst aerodrome

When asked which Australian aerodrome had the greatest wind shear or downdraft problems, about half of the ATC respondents named the aerodrome at which they were currently working. Laverton and Perth were the most named by military and civilian ATCs respectively.

Among civilian pilots, the most named aerodromes were Perth, Sydney and Hobart. When related to traffic density at each location, Hobart and Perth are particularly prominent. Among military pilots, Nowra, Pearce, and Laverton were clearly identified in that order.

Many respondents elaborated on the features of an aerodrome which they believe cause or are associated with wind problems. The main features nominated are:

— runway elevated above the surrounds;
— aerodrome in the lee of mountains;
— in rugged terrain, where short, uncontrolled and one-way strips are used;
— non-uniform airflow occurring over the aerodrome surface giving conflicting windsock information;
— approach paths crossing water;
— noise abatement procedures discouraging the use of the runway with the most favourable wind structure.

Worst aircraft

Pilot respondents were asked their opinions on which aircraft type is most affected by wind shear problems on approach. This seemed to be variously interpreted as:

Which reacts the most? or
In which is recovery most difficult? or
In which is detection most difficult? or
Which is most critical in the landing configuration?

Another problem in the comparison of aircraft types is that certain career streams have only training aircraft in common (e.g. among pilots with experience on the Caribou, very few had experience on Mirage, Porter, F-111C or CT4A).

After due consideration of each pilot's nomination in relation to his experience, the Caribou and the Dakota appeared to be regarded as the most affected fixed-wing military aircraft.

Helicopter pilot responses were analysed similarly. Among RAAF pilots, the Iroquois was considered worse than the Chinook. Among Army pilots, the Sioux and the LOH (Bell 206) were thought worse than the Iroquois. Among Navy pilots, Iroquois and Wessex were regarded as being worse than the Sea King.

A rotary-wing versus fixed-wing comparison was asked only of pilots with adequate experience on both classes of aircraft. The following conclusions were drawn:

Responding pilots who were currently rotary-wing aircraft pilots mostly favoured the *fixed-wing worse* option.

Responding pilots who were currently pilots of Caribou, Tracker, Dakota, Porter, and CT4A aircraft mostly favoured the *fixed-wing worse* option.

Responding pilots who were currently pilots of Hercules, Orion or Mirage aircraft mostly favoured the *rotary-wing worse* option.

From civilian pilot respondents there was a clear trend for swept-wing jet transports to be most named as the *most affected* aircraft. Of these the B-727 and the B-707 were prominent. Qantas pilots usually named the B-707 from an experience profile including B-747, Electra, and DC-3. TAA and Ansett pilots usually named the B-727 from profiles including the DC-9 and F-27. Those with no B-727 experience usually named the DC-9, while pilots with no jet experience usually named the DC-3 as worse than the Electra or F-27. Civilian pilots were not asked about rotary-wing or general aviation aircraft.

Many respondents elaborated on the features of the aircraft which they believe are associated with the aircraft's susceptibility to wind shear.

For light aircraft, wing loading and low approach speeds (by comparison with a given wind change) were often cited. For transport aircraft, momentum and power/mass ratios were often stated to be the major parameters. For jets, engine response times and the lack of propeller slipstream over the wing were stated to be important. The position on the drag curve at which the aircraft operates during approach was said to be a factor for delta and swept-wing aircraft.

STOL aircraft tend to operate in rugged areas with short runways. Consequently, steep slow approaches using high lift devices are used. High pilot workload associated with such operations, together with minimal approach speeds were cited by some respondents as factors. Helicopter pilots cited operations of high aircraft mass for the given density altitude. The mode of operation (confined areas and pinnacles) was thought relevant here also. The requirement for a zero touchdown speed was also mentioned as sometimes important. Some cited high workload on landing in aircraft in which the pilot has no co-pilot or navigator to assist.

Understanding of wind shear terms

The questions at the beginning of each questionnaire served to establish the subject as well as to survey the popular understanding of some relevant terms.

The question: *What is wind shear?* yielded an emphasis on the *abrupt change of wind . . .* answer among all groups of respondents. Some emphasised similarity with words like gustiness and turbulence.

The question: *What is wind gradient?* yielded an emphasis on the *progressive change in wind speed . . .* answer among all groups. It was sometimes noted that the gradient wind was the wind interpreted from the pressure gradient or isobars shown on meteorological maps.

The question: *Which of the following terms do you think is correct when the headwind decreases on descent during final approach?* has the following answers which are correct by definition.

Negative shear (as opposed to positive shear)
Headwind shear (as opposed to tailwind shear)
Forward shear (as opposed to reverse shear)
Undershoot shear (as opposed to overshoot shear)

In the multi-choice answers, the last of these pairs was offered only in the civilian versions of the questionnaire.

For military respondents, the headwind/tailwind option was the most favoured and also the best answered as judged by the correct/incorrect ratios. However, more than half of the military respondents selected *unfamiliar with these terms* rather than either of those options.

Civilian ATCs mostly preferred the positive/negative shear terms, and civilian pilots mostly preferred the overshoot/undershoot shear option. And while fewer civilian pilots selected *unfamiliar with these terms* the correct/incorrect ratios were lower than for military pilots.

Unsolicited comments suggested that the understanding of wind variation problems is related heavily to experience, and that formal training has included little mention of the subject.

Detection of wind difficulties

ATCs were asked: *What do you actually use to detect wind shear or wind gradient so that you can advise pilots on approach?* Multiple selections were allowed. *Reports from aircraft* and *experience with local conditions* were most popular. Visual factors (cloud, smoke, dust, etc.) and meteorological cues were less frequently noted. Approximately 16 per cent of respondents selected *(there is) usually not enough information to judge.* Most of the military respondents with Ground Controlled Approach (GCA) qualifications selected *observations of aircraft on Precision Approach Radar (PAR)* as an important cue.

Experience with local conditions was the most popular answer by pilot groups to the question: *What cues do you actually use to anticipate a wind shear or wind gradient on final approach?* Visual cues (such as smoke, cloud, trees, terrain, surface texture) were the next most frequent reply from pilots of helicopters, Hercules, Caribou and Army aircraft. For other pilots, meteorological correlates (such as turbulence and thunderstorms) and advice from others — including ATC, Automatic Terminal Information Service (ATIS) and other aircraft — were selected more frequently than visual cues.

Military pilots selected visual drift observations more frequently than observations from aircraft instruments. The reverse was true for civilian pilots.

The question on aircraft response in wind shear (decreasing headwind) or downdraft situations yielded increasing rate of descent, decreasing airspeed, and glideslope departures as the major cues. Pitch and angle of attack were each selected by less than 20 per cent of respondents. Army pilot respondents noted yaw and wing dropping more than other groups, especially in wind shear as opposed to downdraft.

To distinguish between wind shear (decreasing headwind) and downdraft, several pilots suggested that downdrafts generally caused a quicker response (especially in rate of descent and glideslope departures) than wind shears. Others suggested that it was difficult or unnecessary to distinguish.

Variations in the *runway picture* — including visual approach slope indicator system (VASIS) information — and the relationship between airspeed and rate of descent (not consequent upon any pilot control inputs) were also cited as subtle cues to wind shear and downdraft. Some civilian pilots of aircraft equipped with Doppler or inertial navigation system (INS) equipment claimed to use their equipment to measure wind aloft (for comparison with surface wind as advised), to detect any change in wind along the flight path as it occurs, and to distinguish between downdraft and wind shear. This technique was less popular with military pilots, especially in single place aircraft where pilot workload would preclude any regular monitoring.

Approach technique for wind shear

Pilots were asked how they would alter their approach speed if they knew that the wind at 500 ft was different from the surface wind. Most selected *no change.* Some noted that they would not know the wind at 500 ft, at least not confidently. Others stated that *there was plenty of time for correction below 500 ft.*

Those who said that they would alter their approach speed in such conditions included 60 per cent of Boeing pilots, and 40 per cent of pilots of propeller transports (including HS748, Caribou, Dakota, F-27, Neptune, but excluding Hercules).

The various methods of altering the approach mostly involved a further margin added to the approach speed. These included:

— add the *shear* (understood to be the wind difference between the ground and 500 ft);
— add five to 10 knots;
— use 500 ft wind instead of surface wind in calculating the approach speed; and
— aim for a minimum ground speed.

Other changes to the flight configuration included:

— use less or no flap;
— fly a flatter approach path;
— fly with a higher power setting (to avoid jet engine response lag);
— fly a decelerating approach allowing airspeed to bleed off;
— have the navigator, first officer or co-pilot *call the wind* every 10 seconds (when suitable instruments are available);
— aim for a long touchdown; and
— be ready for a go-around.

It should be emphasised that the various techniques referred to above are those quoted by pilots and do not necessarily carry any endorsement from aviation authorities or operators.

For STOL aircraft pilots, the occasion when they expect wind changes (irregular terrain, etc.) is often just the situation in which they want their approach speeds to be minimal because of the tendency for runways to be short at remote locations. This is in direct conflict with many of the above. Some pilots referred to other limits to approach speed such as runway surface, braking ability, landing gear and flap speed limits, etc.

Several pilots, military and civilian, referred to pressure to accept a duty runway at city airfields with a downwind component of up to 10 knots. Because of problems related to excessive ground speed, they were reluctant to add margins to their airspeed in such circumstances.

Military ATC respondents with GCA qualifications were asked about altering the approach path of an aircraft in anticipation of a wind shear. The majority gave an affirmative answer. Deliberately bringing the aircraft in high or to one side or the early correction of expected drift were commonly quoted as strategies. Some of those giving a negative answer indicated that they thought that a shear is never 100 per cent predictable, and that an incorrect prediction called for dangerous corrections late in the approach. However,

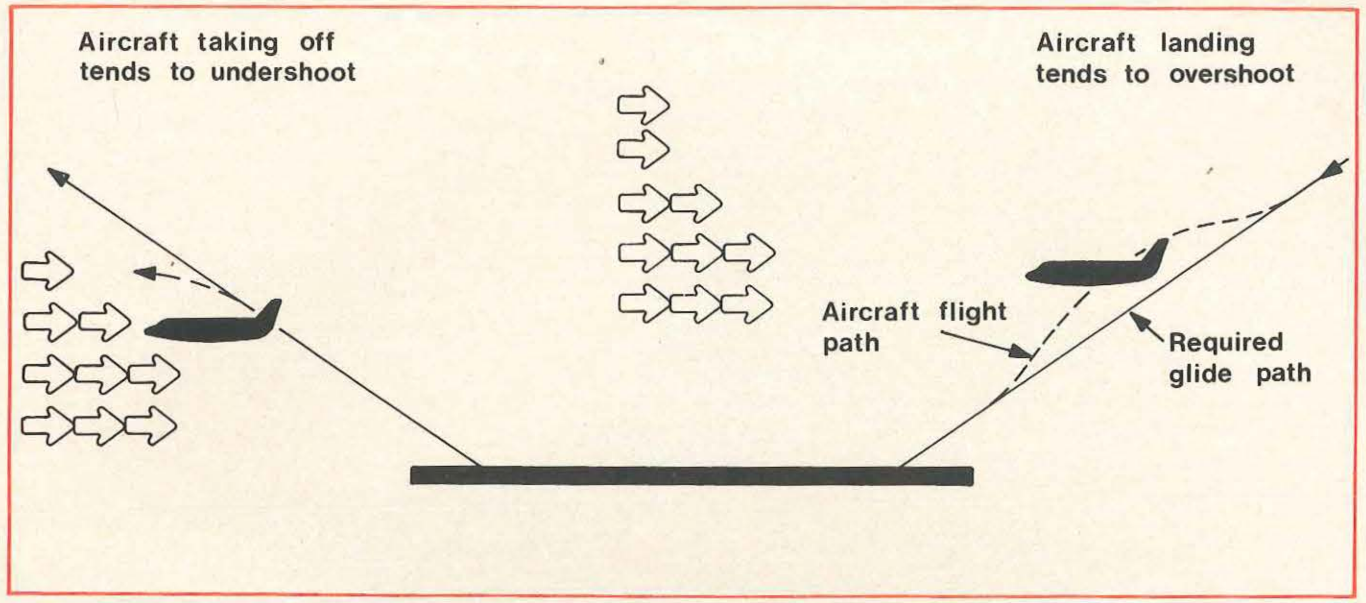


Fig. 2. Head wind component decreasing with altitude

the majority view was that a modified approach path helped to make precise touchdowns possible when wind changes along the approach path were expected.

Warning messages

For examples of typical messages currently given in Australia, both pilot and ATC groups cited a statement of existence such as:—

Caution, wind shear or

Previous aircraft advises wind shear on approach.

Occasionally, a qualitative statement of degree or location of the shear was included, e.g.

Severe wind shear on short final.

The condition for the use of the warning message seemed to be either:

— when a previous aircraft made a report; or
— as a standard procedure when a certain runway was in use, e.g. Nowra runway 26.

Among unsolicited comments, complaints about the inaccuracy of surface wind advice was the most common. Pilots suggested that this was the result of anemometer location rather than ATC's vigilance, and was a problem at some airfields only. It was suggested by some that this was a greater problem than the lack of accurate information about wind aloft.

In addition, several pilots passed comments on the distracting nature of additional information when the pilot is involved in a sequence of landing checks as well as monitoring various instruments and possibly external visual cues. Unless the information is of considerable importance, perhaps the pilot would be better off without it, some suggested. In justifying that opinion, one pilot asserted that an educated guess was almost as good as accurate knowledge of wind because of the healthy margins built into the approach speeds of most aircraft.

Pilot respondents were asked which aspects of flying (training, conversion, operations etc.) would benefit most from the availability of wind shear advice. Most respondents selected the operational type of answers which would encompass their own type of flying. The only exception to this occurred with Army pilots, for whom the number of pilots selecting the non-operational options exceeded the number selecting the operational options. Explanation of the Army pilots' attitude ranged from the desire to be independent and continue to use visual external cues primarily, to the expectation that suitable equipment would be located only at major airfields, and therefore not often useful to them. There was also some suggestion from all groups that an air-transportable or aircraft-mounted device might be received more enthusiastically.

The questionnaire asked about the wording of possible messages for pilots on approach. The civilian version of the questionnaire contained more questions on this aspect than did the military versions.

The simple statement of wind speed at one or two heights above terrain (as well as surface wind) was reasonably popular with most groups and drew no criticisms. Qualitative messages were not frequently nominated. Some pilots pointed out that what is severe for one aircraft may be mild to another.

Aircraft reaction type messages (e.g. expect loss of airspeed, or expect increasing rate of descent) were generally not favoured over wind description type messages, although some pilots said that the former required less mental processing and might be better understood in a critical situation.

Military pilots, in selecting their preferences, avoided the phrases *headwind decreasing,* and *loss of airspeed.* Indeed no indication of the direction of the shear was commonly selected, other than that implied in the wind-at-altitude type message. Other favoured terms among the military pilots were similar to the ones in current use, i.e. *expect wind shear,* or, for a more detailed and quantitative version, *expect 20 knot wind shear at 200 ft.* The latter might be supplied in more severe conditions or on request.

In contrast with the military pilots, few civilian pilot respondents selected a message with no clue about the direction of the shear. The wind-at-altitude type message was preferred as ATIS advice. Boeing pilots and especially B-747 pilots were prominent in this preference. Other than the wind-at-altitude type message, *expect 20 knot increasing headwind below 500 ft*

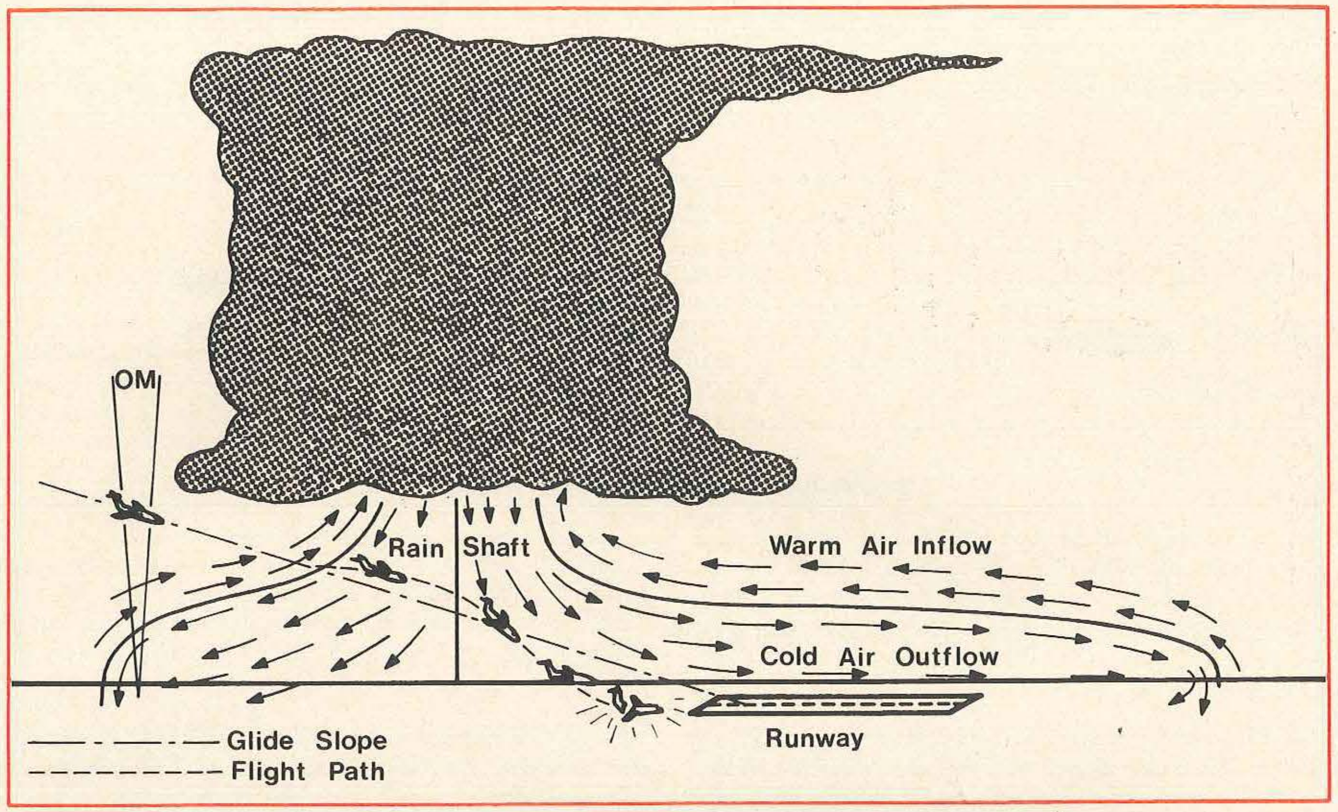


Fig. 3. Typical wind shear associated with thunderstorm.

was the most popular, especially as a message from the tower (as opposed to the ATIS).

Conclusions

Significant factors

The analysis of the pilot and ATC questionnaire replies identified several places and meteorological conditions which are commonly associated with reports of wind shear conditions in Australia. For example, terrain-induced downdrafts at Nowra, Perth and Pearce, and thunderstorm situations at Sydney and Brisbane were clear trends.

Pilots of helicopters and light transports operating in irregular terrain (such as mountainous areas, forest areas, near city buildings, etc.) are often exposed to local wind problems induced by the terrain. Shielding and pinnacle effects are examples. Although the affected areas may be of limited vertical extent, such regions can contain large wind changes and are considered by these pilots to be the major wind shear problem for them. Visual cues for the landing task can be distorted in rugged areas (as a result of loss of horizon reference, irregular shape or slope of field or strip, etc.) so that glideslope angle estimations are more difficult for the pilot, even in conditions of good atmospheric visibility. Accordingly the early recognition of wind shear symptoms is probably more difficult in remote areas than at most regular aerodromes.

Coping with wind shear

The questionnaire results suggest that pilots and ATCs have a diverse understanding of wind shear, its effects and its jargon. The topic has, in the past, not been well covered in formal training. Local knowledge has been developed where needed, but has not always been published in the appropriate aerodrome guides.

In wind shear conditions, the most useful cues available to a pilot are generally rate of descent, airspeed, and visual estimations of glidepath angle and rate of change of glidepath angle.

For detection of wind problems, ATCs usually have only pilot reports and experience with local weather. Some military aerodromes are, however, fitted with PAR and after observing the flight path of several approaching aircraft, the GCA controller can often mentally model the wind structure in terms of its effect upon aircraft, and some of them claimed to allow for this in their guidance strategy.

When data are available (e.g. reports from INS- or Doppler-equipped aircraft, or from other encounters with wind shear) indicating considerable differences in winds at various altitudes, there is good reason for advising pilots of nearby aircraft. This will be useful in planning the approach strategy, especially for stable shear situations. The questionnaire responses indicate that a simple message advising the wind speed and direction at a height of 400 ft above ground (as well as at the surface) would be accepted, understood and interpreted as well as any other verbal message.

When forewarned to expect a change of wind speed on approach, pilots would be better prepared for the encounter and therefore should respond more safely than otherwise.

Acknowledgements

The value of this survey rests largely on the quality of the answers submitted by the 652 respondents. Most of the returned questionnaires appeared to have been answered thoughtfully and sincerely, and particular thanks are due to those who did so.

An information paper entitled *A Questionnaire Survey of Opinions of Pilots and Air Traffic Controllers on Wind Shear in Australia* is available upon request from the Chief Superintendent, ARL, GPO Box 4331, Melbourne, Vic. 3001 ●

A pilot's views on kangaroos

In response to the article in *Aviation Safety Digest 103*, concerning animals on aerodromes, one of our readers provided the following views:

'I am a private pilot with 550 hours, mostly gained since 1974 in operations, by day and night, at private airstrips in the west and north-west of New South Wales.

'In my limited experience, I have concluded that there is no cure for the problem of kangaroos short of mass extermination which, though a desirable ideal to all country people, is somewhat impractical to implement. So, since I am unaware of any remedy to the problem, it becomes a matter of prevention.

'It is well known that these useless, good-for-nothing bludgers (no love lost between country people and kangaroos) are far more active by night than by day, and peak activity can be expected in the hour or so either side of first and last light. Perhaps a lesser known fact, but verified by my observations anyway, is that 'roos run in pairs or multiples of pairs — it is most unusual to see one running alone.

'Armed with this information I restrict my operations as far as possible to broad daylight. This procedure provides reasonable safety simply because the better the visibility, the earlier the warning you will have of any kangaroo movement. Yes, I have seen the flea-bitten mongrels by day, however I have never been concerned by the sight of a 'roo bounding across the runway 100 metres ahead of me — he will be well clear — but it is his b····· mate bounding along behind who is the problem.

'Having being confronted by this situation during both take-off and landing phases, I can make some comments about bush flying that may be of assistance to other pilots, particularly those not accustomed to it.

- At the risk of sounding like a salesman, which I am not, a Cessna is the best aircraft to use and, as long as it is not at max. all up weight, any Cessna will do. If it is at max. all up weight, make sure it has the power to permit the sort of manoeuvres that are occasionally required — maybe a 172XP but for preference, nothing less than a 180 or 182.
- Whatever the aircraft, know it — and know it well. Be sure that you can operate it by feel. If you are an ASI-hog you will not be able to spare the time necessary throughout the take-off or landing to be watching all around for kangaroos — or other animals either, for that matter. Wild pigs can be a hell of a problem and cattle are a straight out b····· nuisance.

(continued on page 31)

Failure to recognise wind shear conditions

Moments after taking off from Tucson International Airport, Arizona, USA, a Boeing 727 struck power lines and two 39 foot poles, the first of which was about 216 metres from the end of the runway. The aircraft was substantially damaged but remained airborne and the crew, after assessing the damage, landed the aircraft safely back at the airport. None of the 84 passengers or seven crew members was injured.

The aircraft was operating a scheduled passenger service from Houston, Texas to Los Angeles, California, with several intermediate stops including Tucson.

Before the flight crew started the engines preparatory to taxiing from the terminal building at Tucson, the airline's station agent prepared the weight and balance form for the flight. The sheet was completed for a 15 degree flap take-off on Runway 11L, the active runway at the time, and was based on a temperature of 35 degrees Celsius and a gross take-off weight of 62 580 kilograms. While parked at the terminal, the crew received a wind report of 210 degrees at 18 knots, gusting to 25 knots, and the second officer prepared the take-off data card for a departure from Runway 29 R. The computed critical engine failure speed, or decision speed (V_1), and the rotation speed (V_R) were both 123 knots, and the take-off safety speed (V_2) was 138 knots. Before taxiing from the terminal however, Runway 21 was selected instead of Runway 29 R, because it was now the active runway and the wind velocity exceeded the cross-wind limits for Runway 29 R.

After the aircraft began to taxi to Runway 21 for take-off, the second officer computed the weight for a Runway 21 departure and advised the captain, 'Well, we're over-grossed without wind.' He also said that a headwind component of 10 knots was needed to meet take-off weight requirements.

During the next few minutes there were numerous rapid changes in wind strength and direction. The tower controller transmitted a series of reports in which the direction of the wind varied between 120 and 240 degrees, and the strength between 13 knots and 40 knots, with gusts to 50 knots. The last reported wind — 170 degrees at 13 knots — would have provided a 10 knot headwind component at the start of the take-off roll on Runway 21.

While the aircraft was taxiing, a dust storm passed over the airport and a discussion between the crew members about the blowing dust was recorded on the aircraft's cockpit voice recorder (CVR). The storm lasted about six minutes and, in the reduced visibility, the crew had difficulty following the taxi route to the runway. After being told by the tower to make a right turn on to the next taxiway, the first officer replied, 'Okay, we got to find it first'. A few moments later, according to the CVR, the captain commented, 'This is just a short-lived thing, by the time we get out there, it will be all gone I think'. Two minutes later, the aircraft was finally in position and the tower cleared it for take-off.

Runway 21 at Tucson is 2134 metres long; for landing, there is a 152 metre displaced threshold, but for take-off, the entire length of the runway is available. The taxiway the 727 used enters the runway 152 metres in from the approach end at the same point as the displaced threshold. After taxiing on to the runway however, the 727 did not back-track to use the full length but instead, began to take off from the intersection of the runway and the taxiway, leaving an available distance of 1982 metres.

The captain said that, for take-off, he used normal take-off thrust and a flap setting of 15 degrees. The number one engine was slow to reach take-off power but at 80 knots, all instrument readings were within take-off limits. According to the CVR, 42 seconds after the aircraft was cleared for take-off, the captain exclaimed, 'Hang on, guys' and two seconds later again another unidentified voice called, 'Keep it going'.

Later, the captain recalled, 'As we rotated, nothing happened. It seemed like quite a long time before we were getting off the runway at all. We assumed we were just slightly off the runway. When I noted that we weren't climbing, I glanced at the airspeed again and noticed that we were slightly above V_2. I increased the pitch attitude above the normal take-off climb and again noted no climb. Then I noted the airspeed dropping off rapidly. I then also observed the wires and that we were going to hit the wires. I decreased the nose attitude to the normal pitch attitude for take-off and applied full power'. He said that he lowered the nose because he was concerned with 'control'. The captain said he did not consider abandoning the take-off at any point on the take-off roll.

The read-out from the aircraft's flight data recorder (FDR) showed that in the five to six seconds before the aircraft hit the wires, the indicated airspeed varied from about 145 knots to 130 knots. The FDR showed that after the aircraft struck the poles it accelerated normally through 160 knots. Once clear of the obstacles, the crew checked the aircraft's flight characteristics and, after advising the tower they were returning to the airport, landed normally on Runway 29 R.

Parts of the two poles and the power lines were scattered along the flight path of the aircraft and pieces of the poles were embedded in the airframe. Both wings, the lower fuselage and the landing gear doors were heavily damaged. The lower surface of the left wing and the entire length of the leading edge flaps showed electrical arcing burns. The lower wing had been punctured in several places causing internal damage and fuel leakage. The right wing had been severely dented and punctured near the leading edge flaps and slats while on the lower fuselage, water and fuel drain masts and an antenna were torn off.

Meteorological information

At the time of the accident, the following wind warning was in effect for the Tucson area but had not been transmitted to the tower:

'Scattered thunderstorms in the Tucson area may produce some wind gusts to about 40 to 55 mph this afternoon and evening along with brief blowing dust lowering visibilities to less than a mile. Precipitation will be spotty and generally light. Caution is advised when blowing dust is visible as wind gusts may be quite strong nearby.'

This warning was issued 13 minutes before the Boeing 727 took off but was not received in the Tucson control tower until 11 minutes after the aircraft had departed. The weather observer explained that transmittal to the tower and other facilities was delayed because of the rush of events and other priorities.

Later, when referring to the wind conditions at the time of take-off, the captain said that, 'Noting the conditions under which I was taking off, I wanted to use all the available runway and I made a point in my mind, as I was taxiing, to go over the bar which crossed the runway and to get as much available runway as possible for take-off.' When the aircraft arrived at Tucson, it landed on Runway 21 but the captain did not recall seeing the displaced threshold during the landing. The captain said he had not been into Tucson Airport for about three years before the accident and though he and the first officer referred to the airport diagram in the approach charts, they did not see the displaced threshold depiction.

The captain added that before take-off, he was concerned about the high gusty winds and the dust that was blowing, and 'since I was already taxiing at that time, I decided to wait and see and continue taxiing. As the dust storm passed, I could see out my left window and it was clear . . . It appeared that everything was back to as before.' The captain stated that he did not anticipate the possibility of a wind shear because 'my previous experience with wind shear is that the winds are quite variable, as much as 180 degrees and, as far as I am concerned at this time, the wind was predominantly out of the southwest . . .'

A pilot in a runway supervisory unit at the end of Runway 11 L, said that shortly before the accident, the winds were variable from the south-west to the north-west at 10 to 30 knots. He added that the wind speed and direction differed between each end of Runway 11 L/29 R. About the time the 727 took off, he noticed virga — streaks of precipitation which evaporate before reaching the ground — in most quadrants and a circular wall of dust move over the airport from the south-west.

Another pilot who watched the 727 take off said that 'as the aircraft broke ground, it yawed abruptly to the right as (if) it had weather-vaned into the wind. Simultaneously with the weather-vaning, the aircraft moved laterally to its left a distance of 15 to 30 metres.' Two firemen observed that, when the aircraft passed the intersection of Runways 29/11 and 21/03, a windsock near the intersection indicated no wind.

Flight recorder

The FDR readout began at a point where the aircraft turned on to the runway to begin the take-off and ended when the aircraft reached an altitude of about 4200 feet above mean sea level. The altitude and heading traces were stable until the aircraft lifted off. At that time, the recorder data trace showed an eight degree heading change to the right. The altitude trace showed a slight climb after lift-off followed by a slight descent after impact with the wires and poles, and then a normal climb profile.

The recorded airspeed increased erratically from zero to 110 knots (13 knots below V_1) and then fluctuated around 110 knots for about 12 seconds before increasing. Eight seconds before the 'V_1 rotate' call, the recorded airspeed dropped to 94 knots and at four seconds before V_1 it recovered to 114 knots. Four seconds after the 'V_1 rotate' call, the airspeed reached about 142 knots, then began to decrease to about 130 knots at impact. After the aircraft struck the poles, its airspeed increased rapidly to about 156 knots, then increased slowly to the highest airspeed recorded — 185 knots — during the climb-out.

The information from the FDR was analysed to determine the probable winds into which the aircraft flew and whether the aircraft could have successfully cleared the poles during the take-off.

Wind effect

Theoretical aircraft performance was compared with actual aircraft performance as recorded on the FDR. Since all aircraft systems, including the engines and the flight controls, were operating properly, differences between the actual and theoretical performance were assumed to reflect the effects of winds.

The plot of the derived horizontal winds indicated that the aircraft encountered a headwind component of more than 40 knots at the beginning of the take-off roll. This headwind component decreased to essentially zero at a point about half-way down the runway. From there, the wind experienced by the aircraft changed to a tailwind that averaged about five knots until lift-off. After lift-off, the tailwind increased at a rate of about 4.5 knots per second to a maximum of about 28 knots at the first power pole.

The FDR data indicated that just after impact with the pole the aircraft apparently encountered an abrupt shift in the wind which permitted it to assume a near normal acceleration schedule.

The derived wind model contained only headwind, tailwind and crosswind components. Investigators believed that at 30 feet above ground level, vertical wind velocities would be negligible. The presence of relatively high horizontal winds supported this assumption.

Take-off performance

In order to determine whether the aircraft could have cleared the poles during take-off, the required rate of climb was calculated for two flight profiles:

— Average rate of climb required to miss the poles from the point at which it was realised that obstacle clearance would be a problem.

— The average rate of climb provided by sustaining the highest probable pitch attitude reached by the aircraft after lift-off.

In the first case, it was determined that when the problem of obstacle clearance was recognised, the angle of attack could have been increased to temporarily establish a steeper flight path and clear the poles. Assuming that a decision was made by the pilot at a point about 216 metres from the obstacle and 20 feet above the ground at an initial airspeed of 135 knots indicated airspeed (KIAS), the average rate of climb required to clear the obstacles by 20 feet in no-wind conditions would have been 780 feet per minute. If flown in winds identical to the derived wind profile, the average rate of deceleration at 780 feet per minute rate of climb would have been about 2.2 knots per second. Thus, the airspeed above the obstacle would have been about 128 KIAS (13 KIAS above the stall warning stick-shaker activation speed) and an estimated pitch attitude of at least 13 degrees would have been required.

In the second case, it was calculated that if the highest pitch attitude reached after lift-off had been sustained, the aircraft would have cleared the obstacle. FDR data and pilot testimony indicated that pitch attitude was reduced shortly after take-off when a drop in airspeed was noted. This probably occurred about 15 feet above ground level. According to the captain, the initial target pitch attitude was about 11 degrees. The FDR data indicated that the airspeed was decreasing through about 138 KIAS when the pitch attitude was reduced. It was determined that, if the aircraft had reached and maintained the 11 degree pitch attitude, it would have accelerated at an average rate of about 2.6 knots per second. With a tailwind increasing at 4.5 knots per second in accordance with the derived wind profile, the airspeed would have been decreasing through about 125 KIAS at the poles and the aircraft would have been at an altitude of about 70 feet above ground level. In the aircraft's take-off configuration the stick-shaker would have activated at 115 KIAS and a stall would have occurred at about 106 KIAS.

Significantly, the calculations for these two cases assumed that the wind effect on the aircraft, derived from the FDR data, did not change as altitude increased. There are several schools of thought regarding the wind velocities at altitude in the vicinity of thunderstorms. The best evidence indicates that vertical wind speeds associated with thunderstorm downdraft activity diminish rapidly below 300 feet and that the direction of movement changes to a horizontal outflow.

Because the captain began the take-off with 1982 metres of runway remaining rather than from the end of the 2134 metre runway, the investigation also attempted to determine what effect the additional 152 metres of runway would have had on the ability of the aircraft to clear the obstacles. Since the wind model derived from the FDR data reflected the total wind along the flight profile actually flown by the aircraft, it was not possible to determine precisely what winds the aircraft would have encountered had it taxied to the end of the runway and used all the available distance for take-off.

Assuming the wind did not change from the FDR-derived model however, a take-off begun from the end of the runway rather than from the displaced threshold, would have resulted in lift-off 664 metres from the power lines, or 167 metres before the point the aircraft actually lifted off. In this case, at an average ground speed of 138 knots, the elapsed time from lift-off to the power lines would have been about 9.5 seconds. The rate of climb required to clear the 39 foot poles by 35 feet would have been about 467 feet per minute and in the existing wind conditions, the airspeed would have decreased to about 121 knots.

The stopping capability of the B727 was also analysed to determine when the take-off could have been rejected and the aircraft stopped on the remaining runway. In the wind conditions derived from the FDR data, it was estimated that the aircraft could have been stopped on the runway if the decision to reject the take-off had been made with at least 670 metres of runway remaining. (No allowance was made for reverse thrust or decision-making time). In this case, a decision to abandon the take-off at V_1 (640 metres remaining) could have resulted in the aircraft over-running the end of the runway.

Take-off procedures

For normal take-offs, the airline's Boeing 727 Flight Manual specified the following procedures:

'At V_R, rotate the airplane smoothly to the take-off climb-out attitude of approximately 13 degrees. The rate of rotation should be approximately two degrees per second. When the airplane is rotated at the proper rate, lift-off will normally occur before reaching 10 degrees of body angle, allowing rotation to be continued until climb-out attitude is reached.

'Excessive rates of rotation must be avoided. If the rate of rotation exceeds the proper rate, it is possible to reach an attitude that will cause the tail skid to contact the runway before the airplane can lift off.

'The airplane will normally attain V_2+ 10 assuming all engines are operating, approximately 35 feet above the runway.'

After-take-off procedures (climb to 1500 feet) specified in the manual included:

'1. The airspeed indicator is primary for establishing pitch attitude.'

There was nothing in the manual which provided for adopting different procedures if variable or gusty surface winds existed or were suspected, or if low altitude turbulence or wind shear existed or was reported to exist.

The airline's wind shear training program consisted of a slide and tape presentation, a simulator program providing wind shear training with emphasis on recognition for both landing and take-off, and class-room lectures and discussions on hazardous weather which covered wind shear. The program also included a comprehensive discussion of wind shear recognition factors associated with thunderstorm and cumulo-nimbus clouds. The training records of each flight crew member showed they had received this training.

In addition to the airline's formal wind shear training program the company published numerous articles on hazardous weather conditions and wind shear in a flight operations publication, copies of which were made available to each pilot. Recognition factors such as virga and blowing dust were also contained in these articles.

Shortly before the aircraft took off, a dust storm several hundred feet high originated to the south-west of the airport and travelled rapidly across the airport in a northerly direction. It was accompanied by high surface winds, variable in direction, with gusts up to 50 knots. Based on witness observations, recorded weather data and the FDR-derived wind model, the Safety Board concluded that this storm was the gust front of a thunderstorm or group of convective clouds which produced strong vertical downdrafts and strong and variable horizontal winds at the surface.

The wind warning in effect at the time of the accident called up strong gusty winds, but neither the Tucson control tower personnel nor the flight crew received this information. According to the weather observer's testimony, a 24 minute delay in getting the information to the users was caused by the rush of events and other priorities. Although National Weather Service procedures do not contain a time limit for hazardous weather dissemination, the Board believed that such severe weather information should be disseminated as soon as possible after it is detected if it is to be effective. This warning would have helped alert the flight crew to a possible wind shear condition.

Avoidance of a wind shear encounter depends on timely alerts and the flight crew's early recognition of possible wind shear conditions. The Safety Board believed that, despite the absence of a specific warning, the captain had other clues which should have alerted him to the possibility of wind shear:

- the tower reported gusts up to 50 knots about two minutes before the aircraft took off
- the winds shifted rapidly, as much as 90 degrees
- a severe dust storm crossed the approach end of the runway as the aircraft taxied to the runway for take-off.

When the aircraft left the terminal, the captain became aware of blowing dust approaching the airport from the south-west. Discussions recorded on the CVR confirmed the crew were aware of this. While taxiing to Runway 21 the captain received several reports of high wind speeds and gusts. The variability of the wind indicated rapid movement or change, which was further evidence of unstable conditions conducive to wind shear.

These recognition factors should have been part of the captain's knowledge of thunderstorms and hazardous weather phenomena. The Safety Board concluded that the airline's training program provided sufficient wind shear information to the captain for his observations regarding the weather at Tucson to have alerted him to the possibilities of wind shear. They should have deterred him from taking-off under the conditions, especially since the wind factor was critical for the aircraft to remain within allowable weight limitations for take-off on Runway 21.

The wind model derived from FDR data showed that the aircraft initially encountered a strong headwind at the start of the take-off roll. This strong headwind decreased as the aircraft progressed down the runway until relatively calm wind was encountered. This calm was followed by a rapidly increasing tailwind. As the aircraft lifted off, it encountered a strong crosswind from the right. Based on the recorded and visual evidence, the Board concluded that the aircraft encountered severe wind shear during the take-off roll and during a critical phase of the departure.

The airline company's Boeing 727 take-off procedures call for a smooth rotation to a pitch attitude of approximately 13 degrees and specify that, after take-off, airspeed is the primary reference for establishing pitch attitude. In this accident, the captain rotated the aircraft first to about 11 degrees and then increased the pitch attitude when he realised the aircraft was not climbing. When he saw the airspeed decrease and saw the power lines, he lowered the nose again.

Aircraft performance analysis and other tests showed that the aircraft could have cleared the poles on take-off if the captain had concentrated on flight path control rather than airspeed loss in a take-off situation where airspeed was erratic. The FDR showed that the average rate of climb was 172 feet per minute. When the aircraft struck the poles its airspeed was about 128 KIAS. The performance analysis showed that maintaining an 11 degree pitch attitude after lift-off would result in a rate of climb sufficient to clear a 39 foot obstacle, though this would have required the pilot to allow the airspeed to decrease to about 125 knots.

While the aircraft possessed additional aerodynamic potential to counter the effects of the wind shear, the increased potential existed in a regime of flight for which the captain had no training or approved operating procedures. Based on the evidence, the Safety Board concluded that the captain could not have been expected to operate the aircraft other than in accordance with prescribed company procedures.

Because the wind conditions which affected the aircraft could be derived only from data generated during the take-off, the Safety Board was unable to determine whether the captain's failure to use the full length of Runway 21 contributed to the accident. A few minutes delay in take-off because the aircraft had to be taxied to the beginning of the runway might have resulted in wind conditions that could have been better or worse than those actually experienced. But even without considering the hazards of wind shear, the captain's failure to use all the available runway in a situation where he needed a 3.6 knot headwind component to avoid an overweight take-off reduced the intended margin of safety.

The recorded CVR conversations 'hang on guys' and 'lost all our airspeed' appear to reflect recognition of unusual conditions. Within about four seconds however, the first officer called 'V_1 rotate.' This would have discouraged any thought about rejecting the take-off at that time even if such an idea was ever entertained.

While the performance analysis showed that the aircraft could have been stopped on the runway if the take-off had been rejected *before* V_1, initiation of the take-off from the displaced threshold rather than from the end of the runway substantially reduced the recognition and decision time, and hence the margin of safety, had any attempt been made to reject the take-off from that point.

Probable cause

The National Transportation Safety Board determined that the probable cause of the accident was the captain's decision to take off under evident hazardous wind conditions which resulted in an encounter with severe wind shear and subsequent collision with obstacles in the take-off path. The rate of climb of the aircraft in these conditions when flown according to prescribed operating procedures was not sufficient to clear the obstacles. However, if the aircraft's full aerodynamic capability had been used, collision with obstacles probably could have been avoided ●

(Condensed from a report issued by the National Transportation Safety Board, U.S.A.)

MD and the weather forecast

Murphy's Aeroplane Company is located at a private airstrip about 30 kilometres from a large regional town. There is a government aerodrome near the town complete with a Flight Service Unit, several aircraft operators and modern engineering shops; however, all the local aircraft owners know that Murphy does a cheap 'hundred hourly'.

One of Murphy's clients lived on the far side of a high mountain range on the opposite side of town from Murphy's strip and had arranged to leave his aeroplane one morning for the 'extra special servicing'. On the way down he landed at the main aerodrome and called into the FSU to collect a copy of the local area forecast. After arriving at Murphy's, the client explained that he was being picked up by a friend in another plane. They were going to be flying all day and would be home late, so the client asked Murphy if he could have his aeroplane delivered to his home as it was needed for an early start the next morning.

'Whoever takes it up can ride one of the bikes back to town and I'll get it later', said the client.

'Okay, I'll get one of the boys to do that for you', replied Murphy. 'How was the weather on the way down?'

'Bit of cloud on top of the hills, but she'll be right', he answered. 'See you later, Murph'.

'Okay, mate'. The other aircraft had arrived and the client and his friend were soon on their way.

It had been a very busy day at the workshop — 'No time to repack those wheel bearings, MD,' said Murphy to the Man in the Dustcoat — and it was late afternoon when Murphy told MD to return the newly serviced aircraft to the owner's property. Not wanting to delay the flight in case he was late for his usual 'few at the local', MD did not bother phoning the FSU to check the weather or give any flight details. The fact that the sky was as black as the inside of the proverbial cow and the wind was blowing a near gale did not worry him unduly. After all, it was only about 20 minutes flying time to the customer's strip if he slipped over the top of the hills — it added about 15 minutes to the flight to go around the range and MD had heard a few of the local pilots talking about 'poking through the cloud'. All he had to do was climb 500 feet above the hills and let down a few minutes later to save all that time.

Inside the cockpit of the aircraft MD found the forecast which had accidentally been left there by the owner. He was staring at it and scratching his head when a gust of wind blew the piece of paper away. 'What the heck!', he thought, 'I couldn't understand it anyway'. Completely oblivious of the surrounding weather and ignoring the rapidly decreasing light, he got into the cockpit and started up the engine.

The taildragger was hard to taxi in the strong wind blowing across the strip, but eventually it reached the end and MD lined it up, in a fashion. Not wishing to delay any further, MD opened the throttle and almost immediately the aircraft swung violently into wind, ran off the strip and into one of the half 44's that Murphy used as strip markers. The wooden prop shattered on the drum and the engine vibrated to a stop. Completely bewildered as to how this had all happened, MD left the cockpit and walked dejectedly back to the hangar.

Later that night in the 'local', after Murphy had clearly and lucidly told MD about the deficiencies in his manipulative skills ('You couldn't fly a kite, let alone a plane'), the local police sergeant arrived looking rather pale and worried. He explained that he had been up in the ranges helping at an aircraft accident which was quite a bit worse than MD's little escapade, and that the investigators were trying to work out just why Murphy's client and his companion had flown up one of the blind valleys in cloud and straight into a mountainside.

Murphy and MD looked at each other and both thought that perhaps the broken prop had been a godsend after all.

You may think the preceding story is a bit far-fetched but it reflects the details held in too many accident records. In the years 1970–1977 inclusive, the following Australian accident statistics were recorded:

Total accidents (powered aircraft)	1687
Total fatal accidents	139
Total fatalities	346
Fatal accidents with weather recorded as a factor	29
Fatalities in weather-related accidents	98

The 29 weather-related accidents being considered occurred during the climb, cruise and descent phases and exclude take-off or landing accidents. Closer study of the records reveals the following:

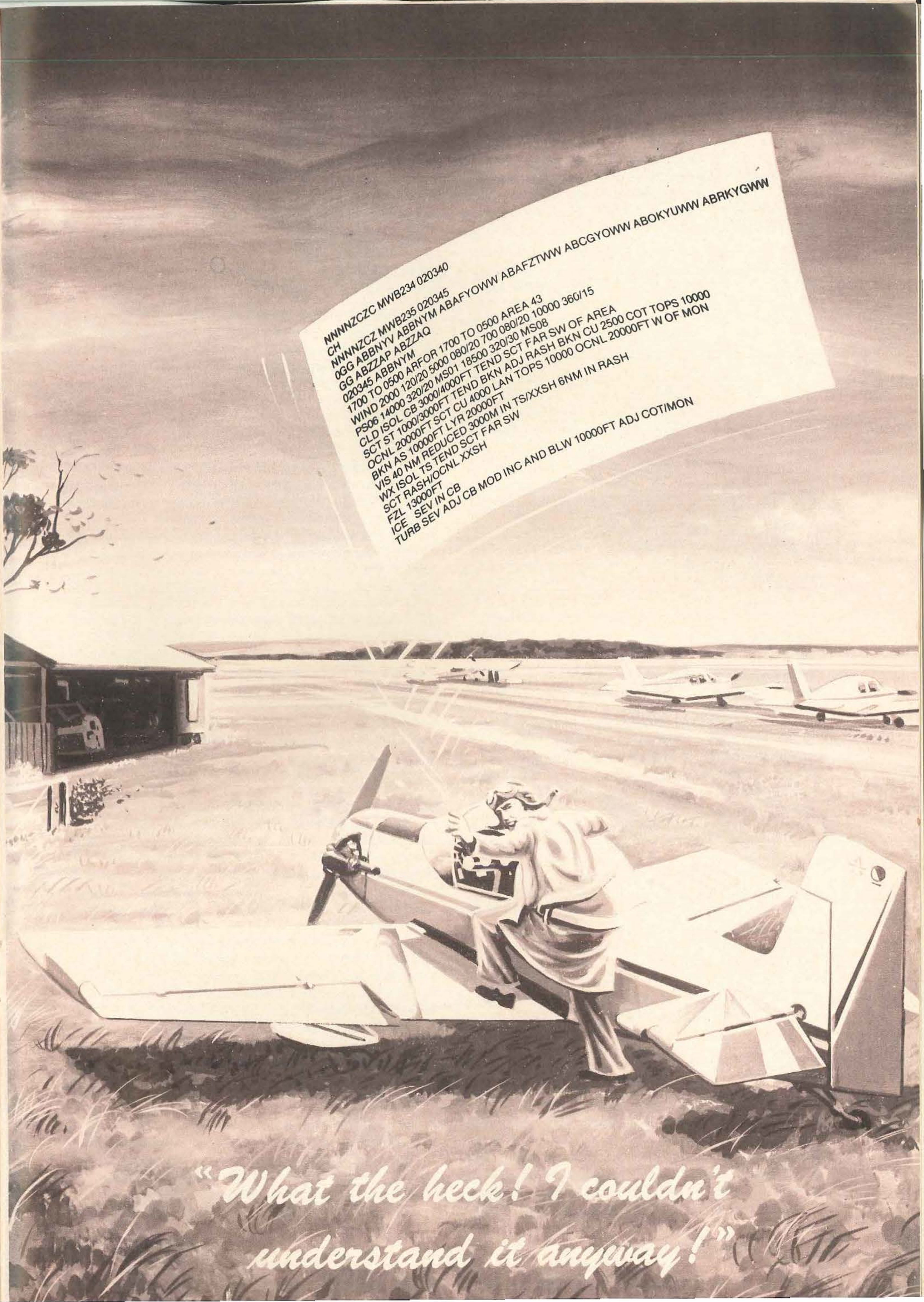
Type of accident	
Controlled flight into ground/water	13
Uncontrolled flight into ground/water	8
Collisions with trees	3
Miscellaneous	5
Phase of operation	
Normal cruise	16
Uncontrolled descent	7
On approach	6
Kind of flying	
Non-commercial pleasure	23
Charter — passenger operations	3
Miscellaneous	3

In more than 75 per cent of the fatal weather-related accidents a forecast was obtained and was substantially correct.

These statistics relate only to fatal accidents; however, there have been dozens, even hundreds of occurrences over the years where pilots became involved unhappily with Mother Nature.

In many Digests we have cited fatal accidents where the pilots were not under any pressure to undertake the flight and where there was virtually unlimited evidence available to them that a successful VFR flight was highly unlikely. For some undetermined reason they decided to 'have a go'.

It is obvious that some pilots do not understand the weather and cannot relate forecasts to their planned flight. To try and alleviate some of this problem, a series of articles on 'meteorology and the pilot' is being prepared for inclusion in future Digests. Meanwhile, readers are advised to study the 1977 edition of the Manual of Meteorology, Part 2, Aviation Meteorology. This book is available from your nearest AGPS bookshop ●



Induction icing

Every year the accident and incident records contain a significant number of occurrences in which induction icing was considered to be the probable cause of an engine power loss. Although this phenomenon is by no means restricted to the approaching colder months of the year, it is an opportune time to once again revise our knowledge of the circumstances leading to induction icing. To assist with this revision we reprint the text of an advisory circular produced by the U.S. Federal Aviation Administration.

Kinds of induction ice

It is important for a pilot to know the kinds of induction system icing and the manner in which each is formed. The three kinds of icing are known as **impact ice, fuel ice** and **throttle ice.**

Impact ice

Impact ice is formed by the striking of moisture-laden air at temperatures below freezing on elements of the induction system which are at temperatures of zero degrees Celsius or below. Under these conditions, ice may build up on such components as the air scoops, heat or alternate air valves, intake screens and protrusions in the carburettor. Pilots should be particularly alert for such icing when flying in snow, sleet, rain, or clouds, especially when they see ice forming on the windshield or leading edge of the wings. The ambient temperature at which impact ice can be expected to build most rapidly is about minus five degrees Celsius when the supercooled moisture in the air is still in a semi-liquid state. This type of icing affects an engine with fuel injection, as well as carburettor engines.

Fuel ice

Fuel ice forms at and downstream from the point where fuel is mixed with the incoming air, if the entrained moisture in the air reaches a freezing temperature as the result of the cooling of the mixture by the vaporisation of the fuel. Moisture may then be precipitated from the incoming air and deposited on the walls of the induction passages as condensation. When the temperature is sufficiently reduced, this condensation accumulates as ice, especially on irregularities of the induction system, such as elbows and joints. If this build-up is allowed to continue, the ice may build up until it effectively throttles the engine. Visible moisture in the air is not necessary for fuel icing, sometimes making it difficult for the pilot to believe, unless he is fully aware of the fuel icing effect.

Fuel icing is not a problem in systems which inject the fuel at a location beyond which the passages are kept warm by engine heat. Thus, the injection of fuel directly into each cylinder, or into air heated by a supercharger, will probably preclude such icing. Fuel icing may occur at temperatures from zero degrees to as high as 40 degrees Celsius, and with a relative humidity of 50 per cent or above.

Throttle ice

Throttle ice is formed at or near a partially closed throttle, typical of a cruising power setting. This occurs when water vapour in the air condenses and freezes because of the cooling caused by the expansion of the mixture as it passes downstream from the restriction caused by the throttle and the carburettor venturi. In conventional float-type carburettors, throttle icing usually occurs in combination with fuel icing, which compounds the rate of ice accretion within and immediately downstream from the carburettor.

Intake ice formation and prevention

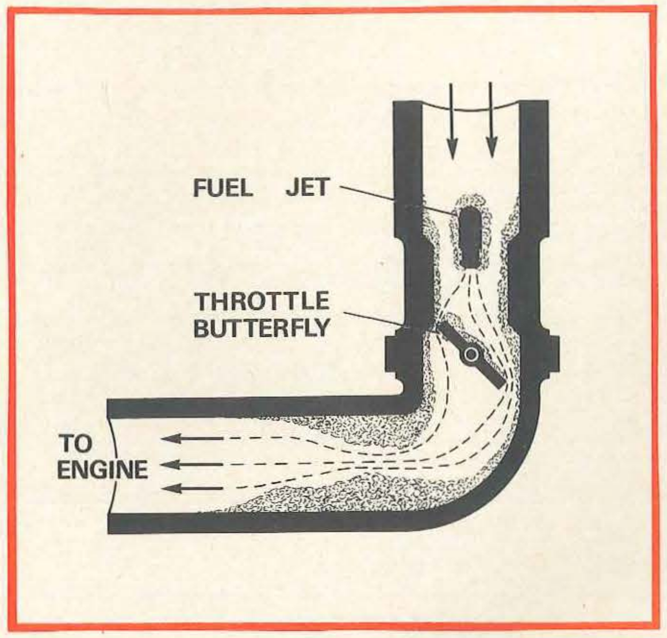
Any one or a combination of the three kinds of induction icing described above can cause a serious loss of power by restricting the flow of the fuel/air mixture to the engine and by interference with the proper fuel/air ratio. It is usually preferable to use carburettor heat or alternate air as an ice prevention means, rather than as a de-icer, because fast-forming ice which is not immediately recognized by the pilot may significantly lower the amount of heat available from the carburettor heating system. Additionally, to prevent power loss from impact ice, it may be necessary to turn to carburettor heat or alternate air before the selector valve is frozen fast by the accumulation of ice around it. When icing conditions are present, it is wise to guard against a serious build-up before de-icing capability is lost. The use of partial heat for ice prevention without some instrumentation to gauge its effect may be worse than none at all under the circumstances. Induction icing is unlikely under extremely cold conditions, because the relative humidity is usually low in cold air, and because such moisture as is present usually consists of ice crystals which pass through the system harmlessly. The use of partial heat when the temperature is below zero degrees Celsius may, for example, raise the mixture temperature up to the danger range, whereas full carburettor heat would bring it well above any danger of icing.

Excessive use of carburettor heat

When no carburettor air or mixture temperature instrumentation is available, the general practice with smaller engines should be to use full heat whenever carburettor heat is applied. With higher output engines, however, especially those with superchargers, discrimination in the use of heat should be exercised because of the possible engine overheating and detonation hazard involved. A pilot of an aircraft equipped with a carburettor air or mixture temperature gauge should make it a practice to regulate his carburettor heat by reference to this indicator. In any aircraft, the excessive use of heat for full power operations, such as take-offs or emergency go-arounds, may result in a serious reduction in the power developed, as well as the hazard of engine damage. It should be noted that carburettor heat is rarely needed for brief high power operations.

Indications of induction icing

The possibility of induction icing should always be considered when the temperature is between zero and plus 20 degrees Celsius, with a relative humidity greater than 50 per cent, or when the temperature is below freezing with visible moisture in the air. The



effect of induction icing is a gradual, progressive decline in the power delivered by the engine. With a fixed pitch propeller this is evidenced by a loss in engine rpm and a loss of altitude or airspeed unless the throttle is slowly advanced. With a constant speed propeller, there will normally be no change in rpm but the same decrease in aircraft performance will occur. With a manifold pressure gauge, a decrease in manifold pressure will be noted before any significant decrease in engine rpm or aircraft performance. With an exhaust gas temperature indicator, a decrease in exhaust gas temperature will occur before any noticeable decrease in engine and aircraft performance. If these indications are not noted by the pilot and no corrective action is taken, the decline in engine power will probably continue progressively until it becomes necessary to retrim to maintain altitude; and engine roughness will occur probably followed by backfiring. Beyond this stage, insufficient power may be available to maintain flight; and complete stoppage may occur, especially if the throttle is moved abruptly.

Preventive actions

To prevent accidents resulting from intake icing, the pilot should regularly use carburettor heat under conditions known to be conducive to icing and be alert at all times for indications of icing in the induction system. The following precautions and procedures will tend to reduce the likelihood of intake icing problems:

— Periodically check the carburettor heat systems and controls for proper condition and operation.
— Start the engine with the carburettor heat control in the COLD position to avoid possible damage to the system and a fire hazard because of a backfire while starting.
— As a pre-flight item, check the carburettor heat effectiveness by noting the power drop (when heat is applied) on run-up.
— When the relative humidity is above 50 per cent and the temperature is below 20 degrees Celsius, apply carburettor heat briefly immediately before take-off to remove any ice which may have been accumulated during taxi and run-up. Generally, the use of carburettor heat for taxiing is not recommended because of possible ingestion of foreign matter with the unfiltered air admitted with the control in the HOT or ALTERNATE AIR position.
— Conduct take-off without carburettor heat, unless extreme intake icing conditions are present.
— Remain alert for indications of induction system icing during take-off and climb-out, especially when the relative humidity is above 50 per cent, or when visible moisture is present in the atmosphere.
— With instrumentation such as carburettor or mixture temperature gauges, partial heat should be used to keep the intake temperature in a safe range. Without such instrumentation, full heat should be used intermittently as considered necessary.
— If induction system ice is suspected of causing a power loss, apply full heat or alternate air. Do not disturb the throttle until improvement is noted. Expect a further power loss momentarily and then a rise in power as the ice is melted.
— If the ice persists after a period with full heat, gradually advance the throttle to full power and climb at the maximum rate available to produce as much heat as possible. Leaning with the mixture control will generally increase the heat but should be used with caution as it may stop the engine under circumstances in which a re-start is impossible.
— Avoid clouds as much as possible.
— As a last resort, a severely iced engine may sometimes be relieved by inducing backfiring with the mixture control. This is a critical procedure at best, should not be attempted with supercharged engines, and must be done with the carburettor heat control in the COLD position.
— Heat should be applied for a short time to warm the induction system before beginning a prolonged descent with the engine throttled and left on during the descent. The pilot should be prepared to turn the heat off after power is regained to resume level flight or initiate a go-around from an abandoned approach.
— The pilot should remember that intake icing is possible with temperatures as high as 40 degrees Celsius and the humidity as low as 50 per cent. It is most likely, however, with temperatures below 20 degrees Celsius and the relative humidity above 80 per cent. The likelihood of icing increases as the temperature decreases (down to zero degrees Celsius) and as the relative humidity increases.

The effects and recommendations described in this circular are general in nature and appropriate to most certificated aircraft. The pilot should refer to all available operating instructions and placards pertaining to his aircraft to determine whether any special considerations or procedures apply to its operation.

Having discussed the formation of the various kinds of induction icing, let us now look at an unusual aspect of one particular kind of icing.

The U.S. National Transportation Safety Board recently investigated the crash of an Aero Commander 560E which had been flying at 11 000 feet when the pilot reported he could no longer maintain altitude because of a power loss from both engines. The aircraft was subsequently being radar vectored to a nearby aerodrome when it crashed into a residential area. The first people to arrive at the accident site noticed that both ram air tubes and the carburettor mixing chambers were packed with ice.

This aircraft was fitted with injection-type, single barrel, low pressure carburettors in which the fuel is introduced downstream from the throttle and beyond the venturi chamber. This design feature virtually eliminates fuel (vapour) ice and reduces the hazard of throttle ice in the induction system. The third kind of icing — impact ice — still presents a problem and may form in the carburettor air inlet ducts, the screen, the elbow, the metering elements and the heat valve.

Because of the favourable characteristics of aircraft fitted with this type of induction system, pilots may not recognise that impact ice still poses a potential hazard for their aircraft. Undue delay in selecting alternate air in some icing conditions may result in an ice accumulation which immobilises the heat valves. Once this has happened, the pilot may be powerless to counter further ice build-up and the engines may subsequently lose all power.

Throughout this article reference has been made to induction icing, not the more common terminology of carburettor icing. The reason for this is to dispel the misbelief that fuel-injected engines are not susceptible to the formation of induction icing. Although the development of injection-type carburettored engines and fuel-injected engines has greatly relieved the problem it still exists, particularly in conditions of visible precipitation.

You are strongly advised to carefully study the Owner's Handbook or Pilot's Manual for the aircraft you fly. Be sure that you know the type of induction system fitted to the aircraft and the correct means available for preventing or overcoming the problem of induction icing ●

Rudder pedals

The following two accounts show how the links in the chain of events which can lead to an accident are so easily formed.

In the first of these, a contribution from a reader, one of the links in the chain fortunately did not develop:

'I am the Chief Flying Instructor of a flying school and have nearly 10 000 hours piloting experience with about 6000 instructional hours, mostly on single-engine aircraft. In the last 12 months I have received approval to conduct twin-engine endorsement training, including the certification of initial endorsements.

'My normal procedure during pre-take-off checks is to read the check list while the trainee completes the checks and responds. On completion of the checklist the trainee provides a take-off briefing including reference to emergency drills. Finally we decide who will control the aircraft in the event of an actual engine failure; this is normally myself.

'On one particular flight, in a Beech B55 Baron, the normal procedures were conducted and the take-off completed without incident. After reaching the training area, I took over control of the aircraft from the trainee to demonstrate a procedure and was surprised to find that my right rudder pedal was still stowed against the floor.

'Needless to say, had the left engine failed on take-off, and the trainee relinquished control to me as we had briefed, an accident would have probably been unavoidable. The only explanation I can offer is that I simply had not thought about checking my rudder pedals for operation prior to take-off.'

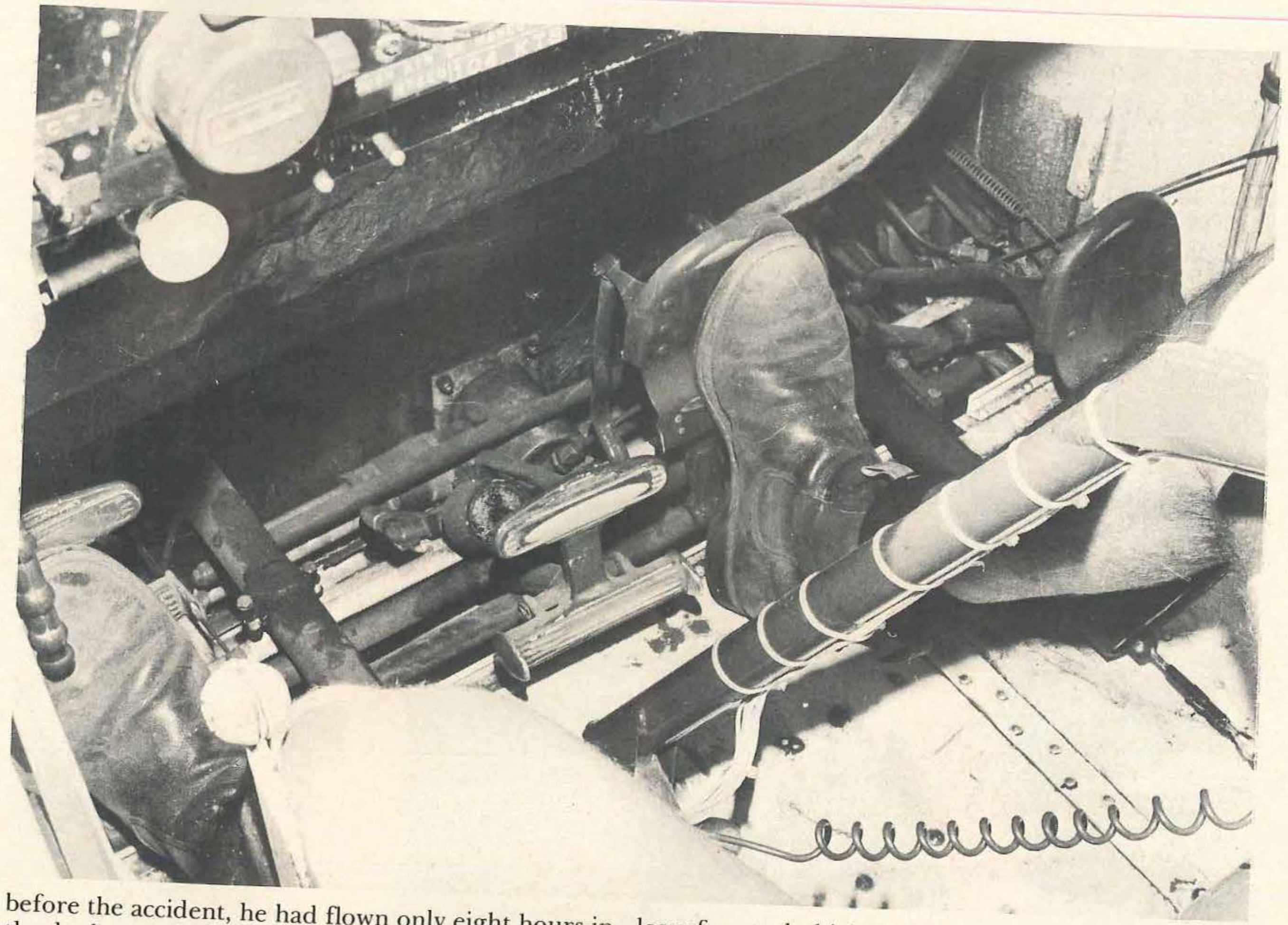
The message in this occurrence is that in a two pilot operation, both pilots should ensure full and free movement of the controls before take-off. In this way the formation of another link in that inevitable chain can be averted.

In the second instance, the aircraft involved, a Piper Pawnee modified for side by side seating with dual controls, was being ferried to an agricultural airstrip. The pilot, who was flying alone, planned to inspect the strip from the air before landing and, about a kilometre from his destination, he began a gentle right turn to line up for his inspection run. At that stage, the aircraft was flying at about 200 feet AGL and 85 knots, with the engine set at cruise power.

As soon as the pilot went to turn right, the aircraft yawed to the left. In an effort to counteract the turn, the pilot applied more right aileron and right rudder, but this only caused the flat turn to tighten. Skidding left through about 120 degrees, the aircraft lost height until, at about 100 feet, it began to buffet, the nose dropped and the aircraft descended rapidly with the wings level until it struck the ground. The landing gear collapsed and, as the aircraft skidded along the ground, it rotated even further to the left. The pilot escaped with minor cuts and bruises.

The aircraft was a special dual-training version of the Pawnee with rather restricted side by side seating. It was equipped with two sets of rudder pedals but measurements showed that the distance between the centres of the left and right pedals on the left set of controls was only 28 centimetres, while in the normal Pawnee, with only one set of controls, this distance is 49.5 centimetres. The space between the two sets of pedals in the two-seat aircraft, edge to edge, was only three centimetres. There were no obstructions between those sets.

Although the pilot had flown about 1400 hours in the normal, single-control Pawnee in the two years



before the accident, he had flown only eight hours in the dual-control version over the same period. He did not positively recall having shifted his feet off the rudder pedals in flight and then shuffled them back again but it is possible that, had he done so, his right foot could well have taken up a more natural position on the adjacent left pedal of the right side set.

The pilot remembered that on an earlier occasion, when taxiing the aircraft, he had momentarily lost directional control and he concluded at the time he had inadvertently placed his right foot on the wrong pedal. In the absence of any other explanation for the loss of control which led to this accident, and in view of his previous experience, the pilot thought it likely he had done the same thing on this occasion.

Dual rudder control installations of this type are not common, and obviously, in such a confined cockpit, it is very important that controls be protected as far as possible from interference and inadvertent operation. As a result of the accident to the Pawnee, the Department is considering the desirability and practicality of some form of shielding or other means of isolating the two sets of rudder pedals in this and similarly modified aircraft ●

(continued from page 21)

- Act as soon as you see the first 'roo. The decision must be positive and immediate — you may not have time to act by the time you see the second one. During the landing phase the decision is easy — abort. If the situation occurs during take-off, you can only do what seems best at the time. In my own experience, I have been surprised at just how well my aircraft performs with full power, high nose attitude and very low speed. But no two circumstances are ever the same so I must repeat that you can only do what seems best at the time. Knowing your aircraft will be of invaluable assistance.

'So that is my two cents worth — it boils down to airmanship I suppose, because that is what safety is all about. My own rules for prevention?

- Don't operate in known 'roo territory at night.
- Avoid the periods of peak activity.
- On approach try to match a slightly nosedown attitude with the slowest possible forward speed as this will provide a good field of vision while also providing a safer starting point to initiate a go-around if necessary.
- Act immediately upon sighting a kangaroo for your best margin of safety. During your take-off run, this may be your only chance to safely abort the take-off.
- If you decide that a safe landing is possible, aim for the very minimum of ground roll that will not destroy the brakes.
- And remember, it is not the first 'roo that will hurt you, but the others following it.

'Finally a word of caution: on your first few encounters it will be difficult not to over-react to the situation. Bitter experience has shown me that over-reaction can magnify this, or any, situation out of all proportion. So the message here is — if in doubt — don't do it!' ●