PRINTED BY HEDGES & BELL LTD., MARYBOROUGH, VIC

AVIATION SAFETY DIGEST

No. 39, SEPTEMBER, 1964

DEPARTMENT OF CIVIL AVIATION

AUSTRALIA

AVIATION SAFETY DIGEST

No. 39 SEPTEMBER, 1964

Prepared in the Air Safety Investigation Branch,
Department of Civil Aviation, Commonwealth of Australia

Contents

Light aircraft line the tarmac at Perth at the start of a 500 mile rally held in Western Australia recently.

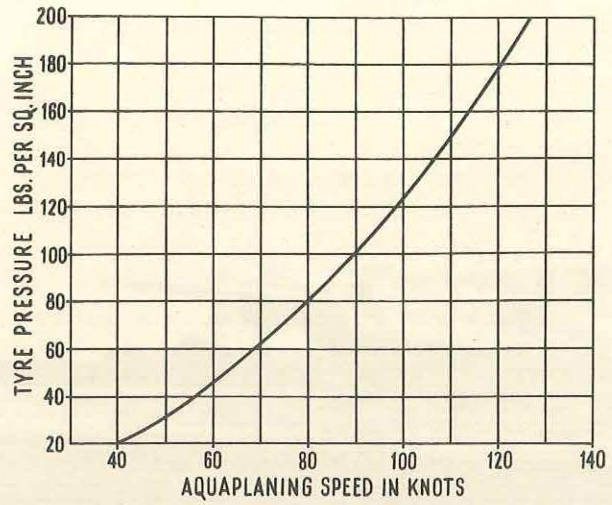
— Photograph by courtesy Air BP

Landing on Wet Runways

We are fortunate that our Australian climate has made our airports almost immune from the hazards of ice and snow which aircraft so frequently encounter on northern hemisphere runways during winter months. Unfortunately however, this immunity does not extend to the conditions in which aquaplaning can occur. The dangers common to wet runway operations and those on ice or snow are loss of braking effect and reduced controllability of the aircraft. If anything, aquaplaning is a greater menace than ice and snow in this regard. Susceptibility to aquaplaning has been accentuated in recent years by the characteristics of modern aircraft types.

When an aircraft is moving on a wet runway, the water lying on the surface acts as a lubricant to reduce the friction between the runway surface and the aircraft tyres. It also produces a build-up of pressure beneath the tyres, so decreasing the load transmitted by the tyres to the surface of the runway and reducing the friction available for braking. As the speed increases, the pressure build-up under the tyres also increases. If there is a sufficient depth of water on the runway surface, the stage will be reached where the load on the wheels is equalled by the water pressure being developed under the tyres and total aquaplaning occurs. The graph in Fig. 1 shows the speeds at which total aquaplaning becomes possible for varying tyre pressures and the following table sets out the tyre pressures and the approximate critical aquaplaning speeds for the aircraft types used in domestic operations in Australia. It will be noticed that the critical speeds are greater in the case of aircraft with high pressure tyres. It is also evident that high landing speeds tend to promote aquaplaning and it is therefore particularly important to avoid excessive touchdown speeds when landing on wet runways. The table also illustrates that aquaplaning can occur during the ground run that follows an abandoned take-off.

Aeroplane Type	Tyre Pressure ps.i. (Main Wheels)	Approx. critical aquaplaning speed-(knots)
Lockheed Electra	130	103
Douglas DC6B	106	93
Viscount 800 Series	101	91
Viscount 700 Series	87	84
Convair 440	72	76
Douglas DC4	72	76
Fokker Friendship	75	78
Douglas DC3	48	63
Bristol Freighter	60	70
DeHavilland Dove	46	61
Piaggio 166	48	63



POSSIBLE AQUAPLANING SPEEDS FOR TYRES

FIG. 1

In addition to the speed of the aircraft on the runway and the pressure of its tyres, the other important factor affecting aquaplaning is the depth of water lying on the runway. A depth of only one-eighth of an inch of water is usually sufficient to induce aquaplaning and smooth or worn tyres can aquaplane in as little as one-tenth of an inch. Conversely, ribbed tread tyres require a greater depth of water, usually not less than one-quarter of an inch. Nevertheless, once aquaplaning is established, it can continue in depths less than that required to initiate it. At Australian airports, it is not unusual for water to collect on runways to depths of one-eighth of an inch or more during periods of heavy rain. In conditions of no wind, a rainfall rate of 75 points per hour can accumulate enough water for aquaplaning on a runway with a cross fall of 1.5 per cent. A cross-wind blowing up this gradient would aggravate the situation considerably as it has been found that even a light wind can hold back water on a runway. Most runways in Australia have a cross fall of 1 per cent., so it can readily be seen that a rainfall rate of 50 points per hour can produce aquaplaning conditions, and that even less would be required if there was a wind blowing against the cross fall of the runway. This is one reason why landings on wet runways in excessive cross-wind conditions should be avoided as far as possible.

The nature of the runway surface itself also has to be considered in relation to aquaplaning, smooth surfaces being more conducive to its onset than those which have a grained or uneven surface. Similarly, smooth touch-downs on wet runways contribute to the establishment of aquaplaning conditions. A firm touch-down should therefore be made when landing on a wet runway as this will literally drive the wheels through the film of water to make positive contact with the runway surface itself.

It is important to realize that even when there is no actual aquaplaning, the braking force available to an aircraft is substantially reduced by the lubricating effect of the water on a wet runway. This braking force is technically known as the brake force coefficient, and the graph in Fig. 2 shows the variation in the maximum obtainable brake force coefficient over a range of speeds for both wet and dry runways. It will be noticed that the brake force coefficients are high on a dry runway and decrease as the speed rises. On wet surfaces however, the brake force coefficients are not only substantially lower to begin with, but fall off more rapidly as the speed increases through the lower ranges. Commencing to brake as soon as possible after landing with the early application of reverse thrust, as well as the use of spoilers where fitted, will help to compensate for this reduced braking efficiency.

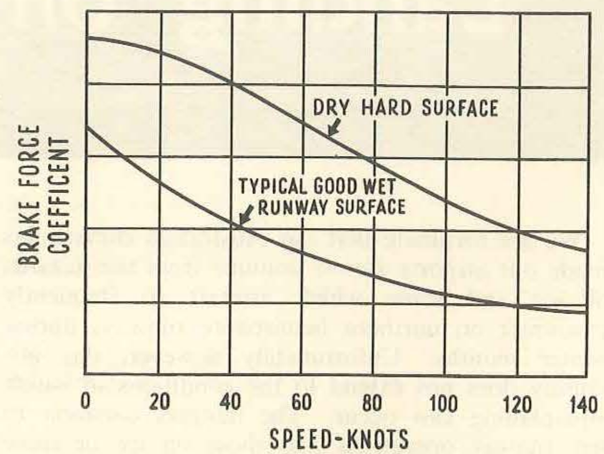


FIG. 2

To see how the maximum brake force coefficient for any given speed can be attained, it is necessary to look at the way the braking force of an aircraft is affected by the skidding or slipping of the tyres on a runway surface. The extent to which tyre skid or slip occurs is expressed as the slip ratio and the graph in Fig. 3 shows how the brake force coefficient varies with the slip ratio. When no braking is applied to the wheels there is no tyre slip because they are free to rotate at the same speed as the aircraft is moving, and so the slip ratio is zero. Conversely, when maximum braking stops the wheels rotating altogether, the slip ratio is 100 per cent. The graph shows that the maximum brake force coefficient is obtained at a slip ratio of between 10 and 20 per cent. In modern aircraft, anti-skid devices are installed to take advantage of this fact by ensuring that the wheels will not lock despite the application of maximum braking by the pilot. Although the most efficient anti skid devices in use are only able to achieve about 70 to 80 per cent. of the maximum brake force coefficient theoretically available at the optimum slip ratio, they are far more effective than braking which is directly controlled by the pilot. Because of this, it is important that these anti-skid devices be used for landings on wet runways to obtain the highest brake force coefficient possible in the prevailing conditions.

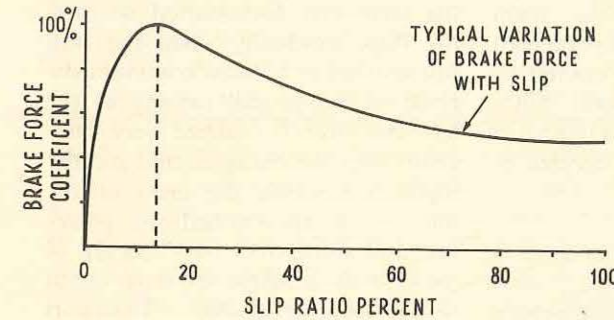


FIG. 3

As has already been mentioned, the risk of aquaplaning is not necessarily confined to landings in the wet. It could occur to an aircraft which has to abandon a take-off in heavy rain. Remote as this possibility may seem, it would be unwise to completely overlook the potential consequences of aquaplaning during such an operation.

In considering the problem of aquaplaning generally, it is worth remembering that once rain has ceased to fall in quantity, it is usually only a matter of minutes before a runway drains sufficiently to preclude the possibility of aquaplaning. There are probably times when it is worth delaying a take-off or landing for a short time to avoid a potentially dangerous situation.

Is Your Lighter Safe?

One overseas airline requires its cabin attendants to caution passengers against the use in flight of a certain brand of plastic cigarette lighter. This particular type of lighter has a plastic reservoir containing visible lighter fluid. To use the lighter, the owner turns it upside down and presses a button which releases fluid from the reservoir to wet the wick. It is then turned upright and the wheel spun to generate the spark to ignite the wick. It appears that if the internal pressure in the lighter is greater than the outside, far more fluid is released than the user is accustomed to under conditions of no pressure differential. The result is a big ball of flame which, on two occasions, caused a fire in the cabin of an airliner.

There may be other types of cigarette lighters that are equally dangerous under certain conditions.

(Extract from Flight Safety Foundation)

STOP PRESS. We have just received an incident report from Western Australia which thoroughly vindicates this warning.

While a Fokker Friendship was flying between Geraldton and Carnarvon with a cabin altitude of 6,000 feet, a passenger had his newly acquired lighter burst into flame when he tried to light a cigarette. The flame ignited the fluid in the lighter reservoir and the passenger was forced to extinguish the fire by smothering it with his coat.

The lighter was of a recently imported type at present being marketed locally for about 12/6. This type has a reservoir filled directly with ordinary lighter fluid, but has no cotton wool or other absorbent packing. It appears to leak freely when subjected to reduced air pressure during flight.

Another Fatal Missed Approach

When the pilot of a Cessna 172 attempted to carry out a missed approach at an agricultural airstrip near Lithgow, N.S.W., the aircraft stalled and crashed. The pilot sustained fatal injuries and the passenger was seriously injured.

The aircraft had been hired by the pilot for the purpose of making a trip from Bankstown to Orange, N.S.W., in company with a business associate. Before departing, the pilot called at the Briefing Office at Bankstown Airport to obtain a weather forecast. Discussing the weather likely to be encountered along the route, the Briefing Officer pointed out that already that day, two other aircraft had abandoned attempts to fly over the ranges because of low cloud, and he strongly advised the pilot not to attempt the flight. Nevertheless, the pilot stated that he would "give it a go". He declined to submit a flight plan or nominate a SARTIME and the aircraft took off for Orange at 1320 hours.

The flight was uneventful until the aircraft began to approach the higher sections of the Great Dividing Range some minutes after passing abeam of Katoomba. Cloud then forced the pilot to descend until the aircraft was flying low over the mountainous terrain and the passenger suggested that they should turn back. By making several northerly diversions from his intended track however, the pilot was able to continue the flight in a general north-westerly direction for another fifteen minutes or so until the aircraft was approximately due west of Lithgow. Further VFR flight westwards then became impossible and the pilot was forced to turn the aircraft on to a reciprocal heading. He maintained this in misty light rain and poor visibility for several minutes with the intention of returning directly to Bankstown but, when the main western railway line was intercepted a few minutes later, he elected to follow the railway. Several miles further on, an agricultural airstrip was sighted and the pilot decided to attempt a landing.

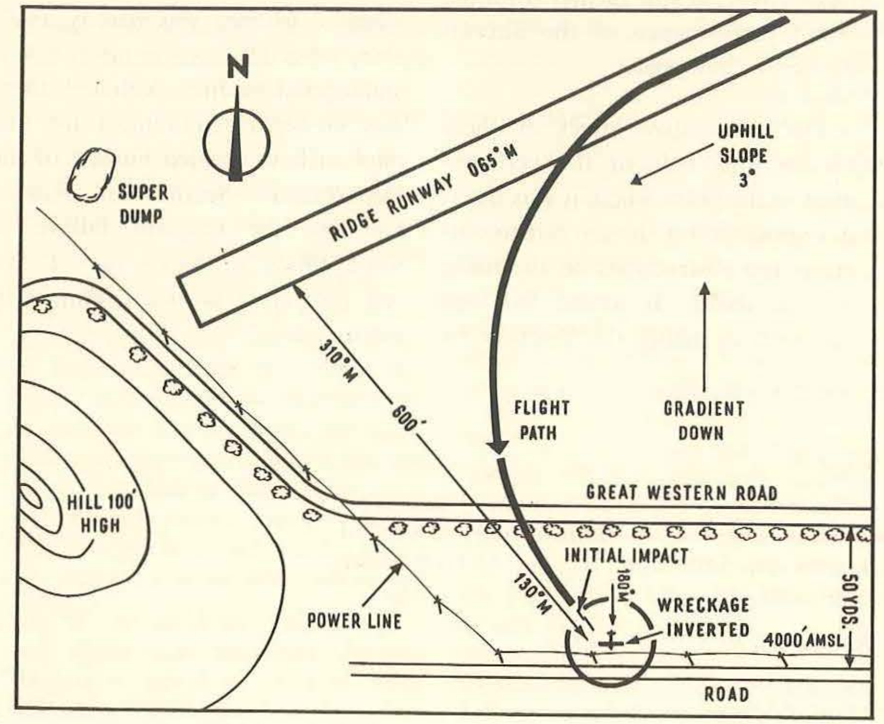
The agricultural strip concerned is situated very close to the Great Western Highway on mountainous terrain 4000 feet above sea level. It is 2000 feet long and has an upward gradient of approximately three degress (1:20) towards a tree-covered hill which rises almost 100 ft. above the upper end of the strip. Looking up the strip from the approach end, the terrain on the left falls away slightly then slopes gently up towards a lightly timbered hill of roughly the same height as the upper end of the strip. The highway and a power line cross this hill before turning to pass immediately above the end of the strip. To the right of the strip, the ground also falls away slightly at first but then rises steeply into a heavily timbered spur.

Because the cloud base in the vicinity of the strip was no more than 300 feet, the pilot had to commence his approach to land from a left base leg made at low level. Landing flap was used but the aircraft overshot, and after traversing half the length of the strip was still several feet above the ground. At this point the pilot abandoned the landing and opened the throttle to make another circuit. He commenced a turn to the left almost immediately to avoid the power line and high ground beyond the end of the strip and had started to raise the flaps gradually when the stall warning began to blow continuously. Even so, while still turning to the left, the aircraft climbed very sluggishly over the rising ground and the highway towards the crest of the hill. As it approached the power line and some trees near the top of the rise at a height of only about thirty feet, it stalled. The port wing struck the ground and the aircraft crashed on its back and slid inverted for several yards before colliding with logs lying on the ground at the base of the trees. The impact flung the tail high into the air against the power line and it slid several feet along the wires before crashing back to the ground. The aircraft finally came to rest upside down 45 feet from the point of first impact and approximately 600 feet from the airstrip.

The accident was witnessed by the occupants of two cars that were travelling on the section of highway adjacent to the scene of the crash. The witnesses hurried to the scene and were responsible for extinguishing a small fire which had broken out in the engine compartment of the aircraft when the fuel filter shattered and splashed fuel on to the hot exhaust system. They also arranged for an ambulance to be called, assisted in extricating the occupants from the wreckage, and obtained the services of a doctor.

A detailed examination of the aircraft wreckage was made but there was no evidence to suggest that any pre-crash defect or failure could have contributed to the accident. It was determined that the aircraft was loaded within its specified limits. At the same time however, it was found that three 14 pound cartons of spark plugs had been carried in the luggage locker of the aircraft without having been secured against movement and that they had been hurled from the locker into the cabin when the aircraft crashed, and one was found to have burst open. It is not known whether the head injuries sustained by the pilot were the result of his having been struck by the cartons. In any case, the pilot did not properly restrain the load as is required by Air Navigation Order 20.16.2.1.2. and thus did not comply with Air Navigation Regulations 227(6) and 227(7).

The pilot held a Private Pilot Licence endorsed for Cessna 172 aircraft. His recorded flying experience was slightly less than 260 hours, and this is assumed to be a measure of his actual experience. It was learned however, that he had fostered the impression at Bankstown Airport that he was a Commercial Pilot of some 3000 hours experience. In fact, on one occasion he had even stated this in writing to the operators of a flying school at Bankstown. The owners of the aircraft in which the accident occurred had hired it to the pilot on the strength of this claim, being satisfied that he would be quite capable of safely assessing the marginal weather that the flight was expected to encounter. Had they known the pilot's actual recorded experience, it is very probable that they would not have authorized the flight. The circumstances of this accident underline the necessity for flying schools and other aircraft operators to examine the log books of pilots before authorizing "in command" flights.



It became clear during the investigation that the weather conditions which prevailed at the time were closely related to the cause of the accident. There was no doubt concerning the accuracy of the forecast given to the pilot and this, together with actual observations of the weather by witnesses, showed that the aircraft had indeed reached a point where it was impossible to continue VFR. By this time, however, the low cloud and rain had increased to the stage where a safe return flight to Bankstown was also very doubtful and so the pilot was virtually committed to a precautionary landing. Although he did not indicate his intentions to the passenger when the aircraft intercepted the railway, it seems that the pilot turned and followed it simply because he had no alternative in the existing conditions. The agricultural airstrip was evidently the first likely landing place the pilot saw amid the rugged mountain terrain, and he grasped at the opportunity it offered.

The fact that the aircraft overshot during the approach to land on the strip is not at all surprising when the circumstances are considered. In the first place, the pilot's total experience was limited, and was spread over a period of some twelve years. During the year preceding the accident he had flown only 22 hours. Secondly, his experience on the aircraft type amounted to only 17 hours. It has been found that inexperienced pilots often misjudge an approach when they enter a circuit area at an unfamiliar height, and so the third factor against the chances of a successful precautionary landing was the necessity for making the circuit at a low altitude. Finally there was the airstrip itself. Such characteristics as its slope and the proximity of obstructions might well have been confusing to the pilot, particularly in the state of mental stress to which he would have undoubtedly been subjected at the time.

As a result of the overshoot, the aircraft was still nearly ten feet above the ground when it was approximately half way up the airstrip. Even so, it is very probable that the aircraft could have been brought to a standstill in the remaining length if the pilot had persisted with the landing. Even if this could not have been achieved, the consequences of over-running the end of the strip would have been far less serious than those of attempting another circuit. An experienced pilot would probably have appreciated this fact, and made the best of the landing in the space that remained.

Once the pilot had opened the throttle and committed himself to a missed approach, his only possible course was to commence a turn to the left. It was obviously impossible for the aircraft to clear the hill directly beyond the end of the airstrip and yet higher terrain lay to the right. The only flight path thus lay towards a hill which, although much lower than the others, was still as high as the upper end of the strip with trees and a power line located near its crest.

This meant that from the commencement of its turn, the aircraft would have had to climb 75 feet before reaching the hill to clear the obstructions. Calculations indicate that at an altitude of 4000 feet it is doubtful if a Cessna 172 could achieve the gradient of climb this would have demanded, even at the optimum airspeed and flap settings. On this occasion however, the performance of the aircraft was severely handicapped by the circumstances in which it had been placed. The fact that the stall warning had started blowing almost as soon as the missed approach was commenced, shows that the airspeed was very low. As well as this, the flaps had been lowered to at least 30 and probably 40 degrees, and the resulting drag would have seriously hindered the aircraft's performance. The aircraft, once it had turned, would also have had a tail wind acting on it and although light, this would have had some effect in decreasing the gradient of climb. Lastly, the effect of the turn itself would have detracted still further from the climb performance of the aircraft at its low airspeed.

The cumulative effect of these factors thus reduced the performance to the point where it was utterly impossible for the aircraft to outclimb the obstructions on the rising ground ahead. It missed the tops of the trees lining the highway by the smallest of margins but it could not gain the additional 15 feet necessary to clear the trees and power line a little further up the hill. The pilot realized that the aircraft was going to collide with the trees and he attempted to tighten the turn to the left to avoid them, but the airspeed of the aircraft was so dangerously low that the increase in the rate of turn induced a stall and the aircraft crashed.

It is apparent that the accident stemmed from the pilot's attempt to carry out a missed approach procedure which was beyond the performance of his aircraft. The weather conditions existing at the time, together with the lack of experience displayed by the pilot firstly in persisting with the flight into adverse weather, and then in misjudging his approach to land, were contributing factors.

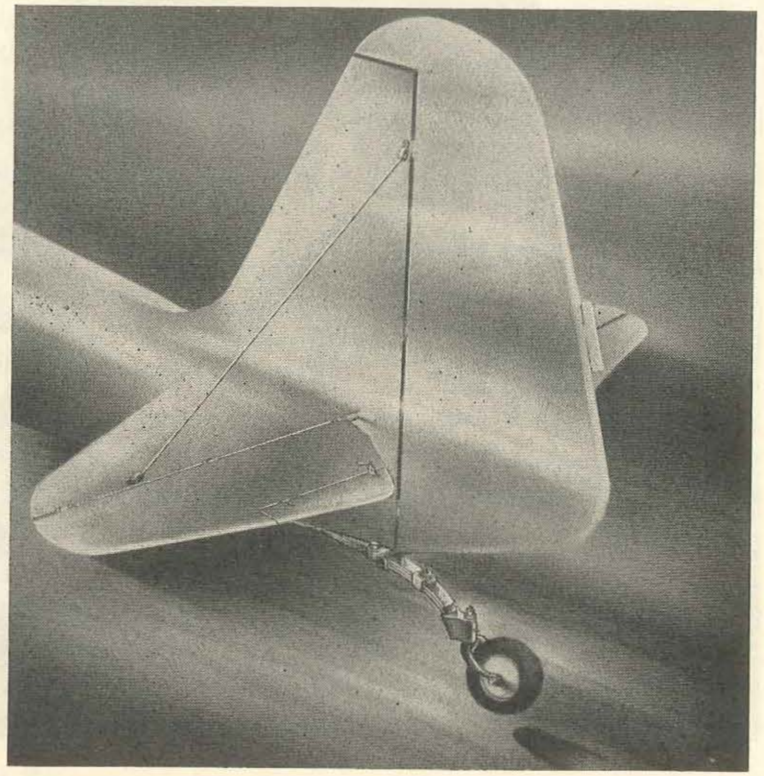
It was fortunate in the circumstances that the site of the accident was so close to a busy highway where assistance was readily available, especially as the aircraft was endangered by fire. Although there was no legal requirement for this pilot to have availed himself of the Department's Search and Rescue facilities, the frequent failure of some pilots to make use of this self protection service continues to surprise us.

ERRATUM

In the article "The Bird Problem", published in the June issue of the Digest, the names of Dr. Gerard van Tets and Dr. H. J. Frith were incorrectly spelt.

We apologize for this error.

Take Your Wheels with YOU!



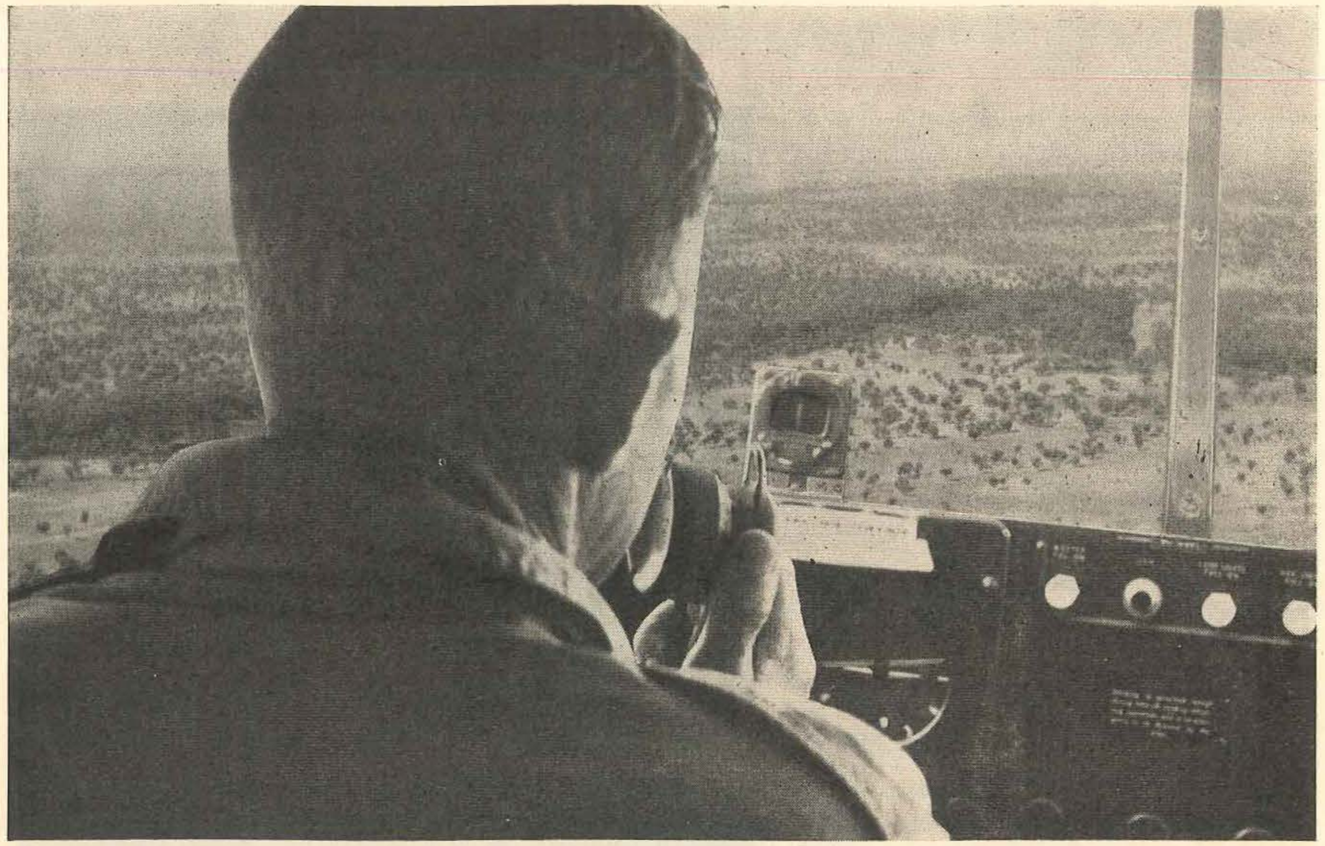
"Where can I locate my wheel?" So wrote the pilot of a light aeroplane in reply to an enquiry from this Department asking if a wheel found on a South Australian country aerodrome had fallen from his aircraft. Incredible as this story may sound, it is true!

When the Senior Groundsman of the aerodrome was making his regular inspection of the movement area, he discovered what appeared to be a tail wheel and fork from an Auster aircraft. It was learned that only one light aeroplane had landed at the aerodrome during the preceding two days and so the Department immediately wrote to the owner/pilot to see if he could shed any light on the mystery. The pilot replied, confessing his embarrassment at the situation but at the same time admitting his relief that the tail wheel had been found! His letter went on to explain how the predicament had occurred.

Most Auster variants are fitted with a solid rubber-tyred tail wheel as standard equipment. The tail wheel is mounted in a swivelling fork which castors on a pivot bolt retained by a castle nut and split pin. To make his aircraft more comfortable on the ground, this pilot had previously replaced the solid-tyred wheel with a pneumatic one, but it was his practice to carry the original tyre and fork assembly as a spare. On this occasion, the pneumatic tail wheel had been punctured after landing so it was removed by raising the tail of the aircraft, undoing the castle nut and pulling out the pivot bolt. The spare assembly was then substituted and the nut replaced and tightened but, **because the split pin had been lost in the grass, the nut was left unlocked.**

The pilot's first inkling that anything was amiss was when he landed back at his home after a flight from the aerodrome concerned. The nut apparently worked loose while the aircraft was taxying on departure and the assembly probably fell off during the take-off run. No damage was done to the aircraft when it landed as the leaf spring to which the tail wheel assembly had been attached, acted as a tail skid.

As the pilot pointed out in his letter, he has learned that nuts will not stay on without being locked. He hopes someone else might benefit from his experience!



False Position Reports — Twice!

The old adage "once bitten, twice shy", probably applies more truly to the flying fraternity than it does to any other group in our community. Indeed, the more prudent ones among us don't wait to be "bitten" ourselves, but rather try to learn something from the mistakes of others.

However, there are exceptions to every rule, and a few pilots not only disregard the warnings contained in accident and incident reports brought to their notice, but even refuse to be cautioned by the results of their own foolhardiness. Having got away with it once, they evidently believe that fortune will smile on them next time they decide to take a similar chance. One example of this form of Russian Roulette came to light earlier this year in Western Australia.

A privately owned light aircraft departed from Kalgoorlie early one morning for an oil drilling site located in desolate and almost uninhabited country more than three hundred miles to the north-east. Atmospheric conditions rendered H/F communication difficult but contact was maintained with Kalgoorlie until the pilot reported "Circuit Area ——, cancel SAR". Two and a half hours later, Perth heard a weak transmission from the pilot requesting them to urgently check the map co-ordinates for the position of the drilling site as he was still airborne and fuel was running low. The owners of the aircraft were contacted for this information and it was then found that the co-ordinates which they had previously given to the pilot were 120 miles south of the true position. By that time the aircraft's remaining endurance was only thirty minutes and after transmitting the Urgency call, "Pan Pan Pan", the pilot advised that he was heading for a dry salt lake to make a landing. Twenty minutes later he reported he had landed the aircraft safely on a track at the edge of the lake. A search aircraft was sent out to establish the actual position of the landing, and arrangements were made for a police ground party to carry fuel supplies 160 miles overland to the site. The aircraft was flown out the next day.

When interviewed, the pilot stated that he had transmitted the circuit area report on the basis that he had identified himself in the general area of the co-ordinates given to him as the site of his destination. Some forty minutes later, when he had still not located the actual camp site, he had tried to call Kalgoorlie but his transmission was not heard, presumably because of prevailing atmospheric conditions. Still confident that he could locate his destination, he had continued searching and making communication checks until his calls were finally heard by Perth, but by this time his fuel was so low that he could neither fly on to the correct location nor divert to an alternative aerodrome. Although it was established that the flight had been well planned and the pilot was not to blame for the error in the position of the drilling site, his decision to pass a circuit area report and cancel SAR before positively identifying his intended landing point was extremely poor airmanship. His subsequent action in remaining in the area without radio contact until his fuel was almost exhausted was similarly inept and was the source of much effort and expense on the part of those responsible for Search and Rescue action. It may not be entirely inappropriate that the date on which this flight commenced was 1st April!

One could be pardoned for concluding that this pilot had learned a valuable lesson and that his future judgment would be qualified by his humiliating but educational experience. Regrettably, some six weeks later this same pilot committed the same error, under different but perhaps even more hazardous circumstances. This time he was flying from an oil drilling site to a small township situated just under 200 miles to the north-east. The flight departed late in the afternoon and according to the flight details passed by radio to Kalgoorlie, the ETA at the destination was only one minute before last light. Nevertheless the flight appeared to proceed normally, and punctually on the ETA Kalgoorlie received a report "Circuit area ——, finished for the day, Goodnight".

Fifteen minutes later, a trunk line call was received in Kalgoorlie from the Postmaster of the township concerned, advising that an aircraft was circling the town in darkness and that vehicles were being organised to form a flare path on the airstrip. Kalgoorlie then tried unsuccessfully to contact the aircraft and the Uncertainity Phase was introduced. A second trunk call a few minutes later reported that the aircraft had landed safely, and the Uncertainty Phase was then cancelled.

The pilot's explanation on this occasion was that adverse winds had retarded the aircraft's progress and that he had given his circuit area call when he had sighted the lights of the town. At this time he was in fact fifteen minutes from his destination. Quite obviously the pilot chose to jeopardise the safety of his aircraft and his three passengers by relying on someone to notice his arrival and arrange a flare path when, by merely advising Kalgoorlie of an amended ETA, he could have ensured that all concerned were alerted to the emergency and that all possible facilities would be available to facilitate a landing in the dark. As it transpired, it was fortuitous that the Postmaster of this very small settlement noticed the aircraft and was able to take the correct action to assist the landing.

This pilot was lucky. Although he had chosen to stubbornly disregard the warning of his own earlier experience, he suffered only the indignity of having the error of his ways pointed out to him in a more direct manner. The history of aviation is studded with cases of pilots who have not been nearly so fortunate.

NOT CLEAR

After the crew of a Viscount had completed the "before take off' check list and reported "Ready" at Sydney Airport, the tower advised the aircraft to "Line up behind the light aircraft on final". This was read by both pilots as "Line up — light aircraft on final", which implied to them that after lining up, a take-off clearance would follow and the light aircraft would then be cleared to land.

As the Viscount entered the runway, the First Officer pointed out a Cessna 172 on final approach, and at the same time the tower called "Negative line up . . . .". However, the warnings were too late and the Cessna was forced to make a missed approach.

The incident serves as a reminder that all tower instructions must be clearly understood, and that it is still prudent for pilots to make a visual check to ensure that the runway is in fact clear. We in turn will try to see that our own phraseologies do not contribute to such situations. In this instance, a more appropriate instruction would probably have been "Cessna on final, — line up behind that aircraft".

Lightning and its effect on aircraft operations has long been one of the "mystic" sciences to most members of the aviation industry. Recently however, the Lockheed Aircraft Corporation devoted an entire issue of their Field Service Digest to one of the most informative condensations of this subject that we have yet seen. We are grateful to the Lockheed Corporation for their permission to reproduce most of this study in our Aviation Safety Digest.

The study is divided into three primary parts:

Part I — A Basis for Discussion.

Part II — Further Thoughts and Considerations.

Appendix — The Origin of Lightning and its Global Aspects.

We have reproduced Part I in this article and it is our intention to include Part II in the next issue.

The appendix is quite a lengthy study of the theory of lightning and because of its size and because we believe its detailed technical content would have a limited appeal, we do not propose to reproduce it. Nevertheless, to those who are interested in the whys and wherefores of lightning, we highly recommend a reading of this Appendix. It has been written by the Editor of the Lockheed Service Digest and its scope is best described in the words of his introduction:

"This rather large Appendix to the article is felt to be justified because of the almost universal ignorance of many persons on the subject of lightning. No offence is meant here, for the writer was, until recently, well established in this group. Now, as much as he has learned about lightning is written into this extensive supplement.

"The story of lightning encroaches on so many highly specialized areas of basic sciences that it is perhaps not surprising that experts on the subject are so few. However, this is not the only problem: scientific facts and theories to explain them are being discovered and formulated from day to day — the picture is forever changing. It is only in the last 20 years or so that the mechanism of lightning came to be understood. And it is only in very recent years that its significance and its connection with an almost closed circuit involving the earth's surface, the ionosphere, and the thundercloud was appreciated. Specialists in environmental electricity, so-called, now endeavour to link this vast circuit with others involving solar radiation and the newly-discovered Van Allen belts above, and the internal current generated by the earth's liquid core below.

"However, we had to stop somewhere. We have chosen some simplified versions of some well-established theories in order to describe lightning. It is acknowledged that these theories are possibly already outmoded by events, but we rest on our own theory — that any theory that helps an explanation is a good one".

If you are interested in the theoretical aspects of the subject, we strongly advise you to obtain a copy of the Lockheed Field Service Digest No. 34, March, 1964. Although it is unlikely that the Department will be able to satisfy all demands, we will try to assist by making two additional reproductions of the Appendix available at each of our Regional Offices so that a copy may be obtained on short term loan.

LIGHTNING AND AIRCRAFT

Part One - A Basis for Discussion

By A. W. TURNER,
Lockheed Flight Test Division Engineer

A little over two hundred years ago on a showery spring day in a small French town near Paris, an old soldier named Coiffier neared the climax of a beautifully simple but dangerous experiment suggested by the American, Benjamin Franklin. With the rumbling of thunder in his ears, Coiffier gingerly brought a grounded conductor closer to an iron rod, insulated from the earth and reaching upward 40 feet toward the black cloud overhead. The old man's heart must have skipped a beat as the first electric spark crackled across the gap. He rushed to bring the village priest to witness this proof that clouds containing lightning, as Franklin had predicted, did carry electricity and that this electricity could be brought to earth with conductors.

Coiffier's employers, scientists D'Alibard, de Lor, and Buffon, soon repeated the experiment themselves and quickly spread the word throughout Europe of Franklin's genius and of the success of his plan.

Meanwhile, in Amercia, Franklin, impatient with delays in construction of his own similar experimental rig, conceived the even simpler scheme of bringing the cloud's charge to earth along the string of a high-flying kite. His friend and contemporary, the English scientist Joseph Priestley, tells of the historic event . . .

"Preparing, therefore, a large silk handkerchief and two cross-sticks of a proper length on which to extend it, he took the opportunity of the first approaching thunderstorm . . . The kite being raised, a considerable time elapsed before there was any appearance of it being electrified . . . at length, just as he was beginning to despair of his contrivance, he observed some loose threads of the hempen string to stand erect and to avoid one another, just as if they had been suspended on a common conductor. (The string ended in an insulating silk ribbon.) Struck with this promising appearance, he immediately presented his knuckle to the key (hung on the string) and — let the reader judge of the exquisite pleasure he must have felt at that moment — the discovery was complete. He perceived a very evident electric spark . . . This happened in June, 1752, a month after the electricians in France had verified the same theory, but before he had heard of anything they had done."

Thus almost simultaneously on both sides of the Atlantic, the most significant single discovery as to the nature of lightning (that it is electrical) was made. Shortly thereafter, his further efforts led Franklin to conclude that, ". . . . the clouds of thundergusts are most commonly in a negative state of electricity, but sometimes in a positive state — the latter, I believe is rare."

The importance of his work in increasing man's understanding of his environment is expressed by Dr. B. J. Mason, Professor of Cloud Physics at the University of London in his recent book entitled, "Clouds, Rain and Rainmaking": "This statement of Franklin's remained the only direct and reliable information on the subject for 170 years and even today, we would wish to modify it only to the extent of replacing **clouds** by **bases of clouds.**"

NATURE AND CAUSE OF LIGHTNING

Although there hasn't been another Benjamin Franklin, the two centuries since his work ended have not been devoid of accomplishment. In fact, in the last 50 years we have seen a great resurgence of interest and progress in the sciences of meteorology and electricity which, through the use of airplanes, high-speed cameras, and a wide variety of electrical

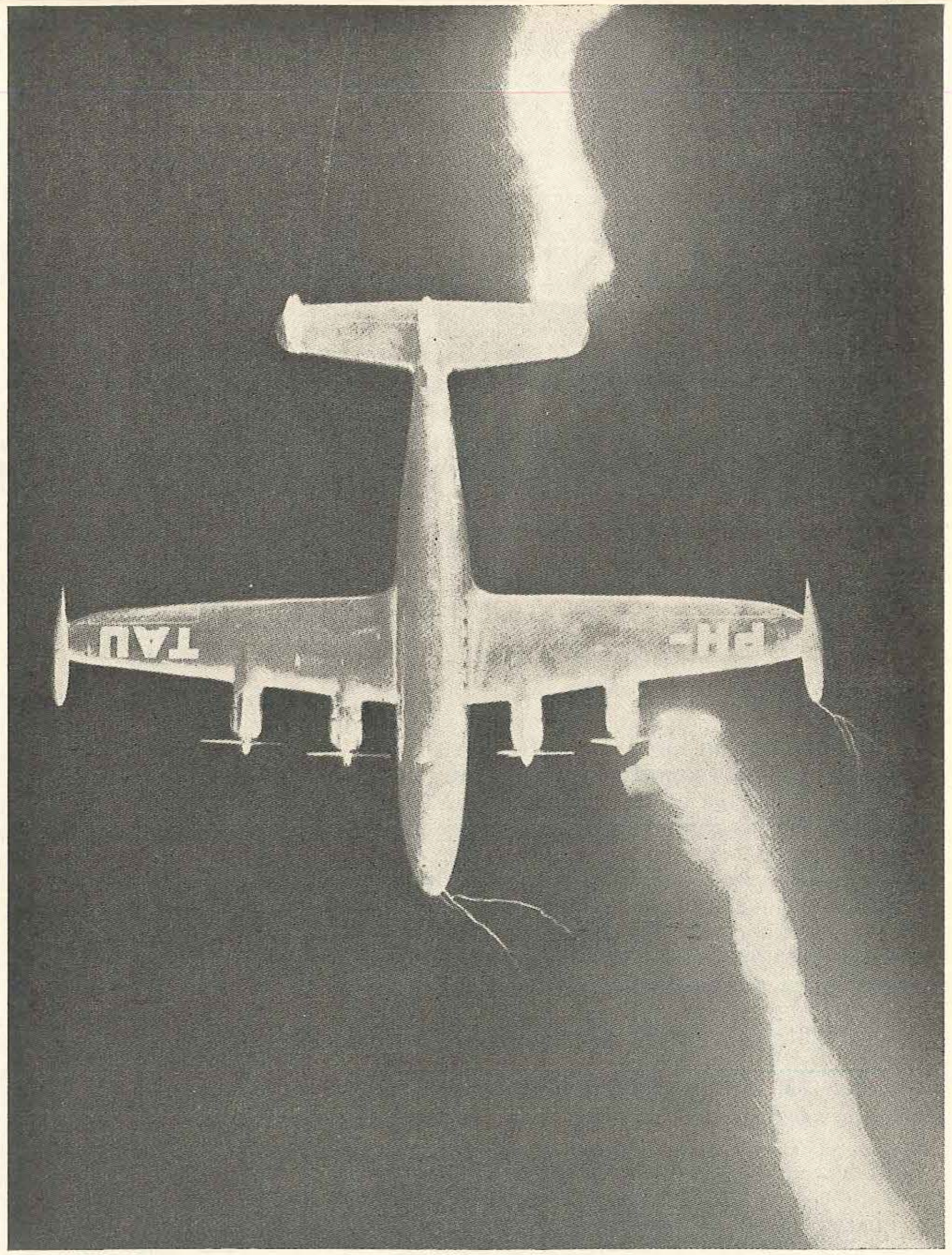


Figure 1

Artificial Lightning Discharge to Metal Model of Constellation

and electronic instruments has added more and more to the understanding of the nature and causes of lightning.*

Perhaps the most significant single discovery in this period was made by Dr. B. F. J. Schonland of South Africa. Using an improved version of a revolutionary high-speed camera invented by the Englishman Sir Charles Boys, Schonland and his associates found that a lightning stroke from cloud to ground is not simply one great spark of electricity leaping suddenly across the gap between two separated charge centres, but instead consists of a complex sequence of events. This sequence is described and illustrated in some detail in the Appendix to this article, but a few brief words on the subject at this point are appropriate.

Photographs show that the first **visible** evidence of activity is in the form of a "stepped leader," a faintly luminous trail of ionized gas which reaches downward from the cloud in distinct spurts (or steps) about 150 feet in length. The leader twists, turns, and divides as it encounters vague "walls" of higher resistance in the atmosphere. As this leader carries the cloud's charge nearer and nearer to the ground (or other electrical charge center), it violently accelerates ionization in the air surrounding adjacent regions of low potential in the earth, to the point that luminous ribbons, similar to the stepped leader, grow from the ground toward the cloud. These are commonly referred to as positive streamers. One of these streamers eventually contacts the oncoming stepped leader and a conductive path is established between the two charge centres. This preliminary process usually takes only some few thousandths of a second.

When the ionized (conductive) path is completed, there is a tremendous surge of electrons down the path, creating the brilliant flash and explosive sound we associate with the lightning bolt. This rush of electrons quickly drains the charge from one portion of the cloud, at which time a new stepped leader may grow from another nearby charge area in the cloud to this suddenly depleted area and, if the original ionized path is still intact, another surge of electrons will occur.

Figure 1 shows a stroke, produced artificially at the Lightning and Transients Research Institute, to a metal model of a Constellation. This photograph is included to show the positive streamers emanating from the nose and wing tip similar to those discovered by Schonland growing from the ground in the cloud-to-ground stroke sequence. A picture taken a split second earlier, just before the flash, would have shown another streamer, somewhat longer than those from the nose and wing tip, emanating from the propeller that was struck.

Schonland states that three strokes per bolt is average, but it is not uncommon for as many as 14 successive strokes to occur along the path established by a stepped leader. (It is the multiple flash process which creates the impression of flickering which we have all noticed in large electrical storms). In fact by study of this phenomenon, Schonland has theorized that since the most frequently observed time between such flashes is 3/100 of a second and the most frequent velocity of the stepped leaders is 130 miles a second, the average distance between cells within a thundercloud is $0.03 \times 130 = 3.9$ miles.

Although data gathered from cloud research indicates that there is considerable variation in this distance between charge centres, it is significant to aviation to note that it is always expressed in **miles** and not feet or thousands of feet — vast dimensions indeed compared to even the largest aircraft. It is recognized of course that aircraft do not normally fly inside thunderclouds. However, the above dimensions do set the scale, and we might add that aircraft

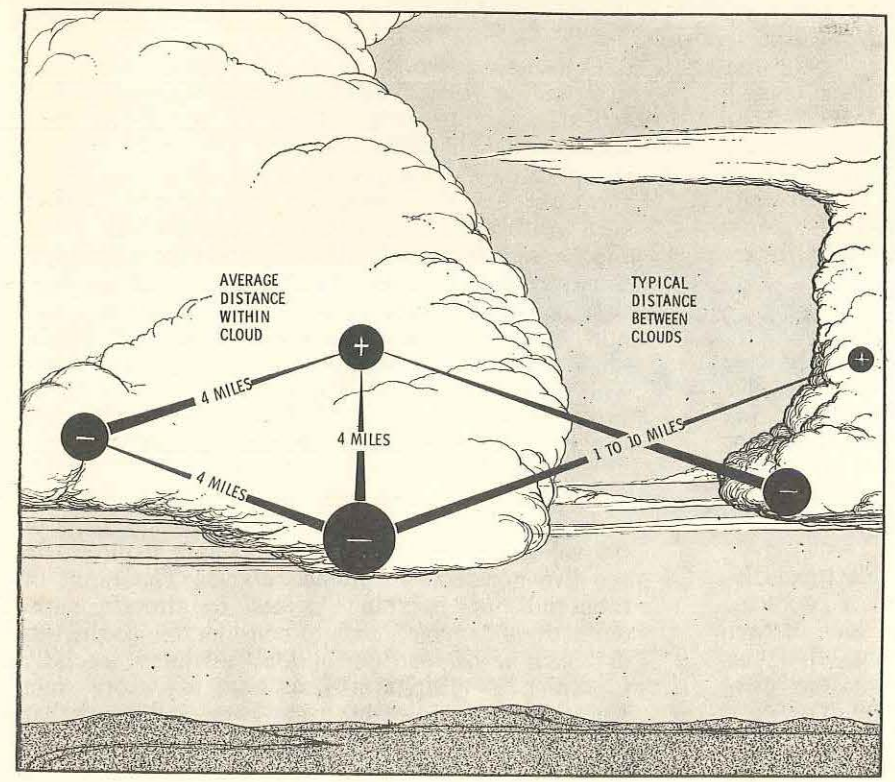


Figure 2

Typical Distances Between Thundercloud Charge Centers

*Regarding the nature of lightning, most research has necessarily been concentrated on strokes between clouds-and-ground. Most of the findings in this article are therefore concerned with this "type" of lightning even though most strikes to aircraft involve strokes between cloud centers. However it has been established that the mechanism in all types of lightning strikes to aircraft follow the same general rules.

frequently intercept lightning strokes between **different** clouds where the intervening distance between charge centres far exceeds Schonland's estimate for charge-centre distribution within a single cloud.

Probably the next most significant area of study of lightning has been the development of theories, from experimental work carried on by hundreds of scientists all over the world, regarding the basic process whereby the electrostatic charges in thunderstorms are built up and separated from each other. There have been perhaps two dozen prominent theories proposed to explain this phenomenon, based on a variety of contributing causes such as the selective charging of droplets, freezing of droplets, shattering of drops, and many others. Laboratory experiments have proved that the processes described by many of these theories can build up charges, but no theory has been accepted as adequate to explain the distribution and build-up rates of charges known to exist in thunderstorms. This, then, is still a very active field of meteorological research and is receiving the attention of many research scientists.

PROBLEMS RELATIVE TO AIRCRAFT

Of more immediate interest to the manufacturers and operators of aircraft is the research work which has been done studying the relationships of aircraft to atmospheric electrical phenomena. These phenomena include such things as precipitation or "P" static (radio interference caused by the leaking off of charges accumulated by the aircraft from friction and/or passage through a charged region in the atmosphere); St. Elmo's fire (a visible corona caused by accelerated charge leakage, indicative of high charge gradients often portending a lightning stroke); and the lightning strokes themselves. All of these phenomena may be encountered under similar conditions and often together. "P" static and St. Elmo's fire, however, are not necessarily accompanied by lightning.

Precipitation Static is very annoying and, by interference with proper functioning of electronic devices, it can cause serious navigation and communication difficulties. This form of electrical interference increases with airplane size and speed, and it is only because of progress in detailed design of static dischargers that these effects have now been reduced to an acceptable level.

St. Elmo's Fire, as a visible evidence of electrical discharge at a tolerably slow rate, is not a problem, does not cause any form of damage, and in fact serves in a positive sense as a warning that the environment is electrified, and lightning may possibly occur.

LIGHTNING STRIKES These are generally considered more of a nuisance than a hazard, particularly when compared with turbulence and icing, which are the primary dangers from thunderstorms. Although lightning can cause damage of varying degrees to aircraft, it is only rarely of a serious nature. This statement is supported by statistics recently released by the U.S. Air Force which indicate that, during the five-year period from January 1959 through December 1963, there was only one major Air Force accident in which lightning was believed to be the primary cause.

The record for commercial aviation is even more impressive. As far as we are aware, lightning has yet to be pinpointed as the primary cause in the destruction of an all-metal airplane, but there have certainly been two accidents in which the cause has so far not been established, and which could have involved lightning. Even allowing for these two cases as "possibles", the risk from lightning is undoubtedly at a level far below risks which are commonly accepted as part of normal everyday living.

An Area Requiring More Research. It has long been the practice in aviation circles, however, to explore avenues which could possibly lead to safer flight. There are certain similarities in the two aforementioned accidents: As well as their possible connection with lightning, both of them seem to have also involved integral fuel tank explosions, but the exact mechanism of ignition has not been explained in either case. It should perhaps be emphasized that the aircraft concerned were of different type and manufacture, and both of them conformed to or exceeded the established requirements for lightning protection.

Considerable work has already been done towards determining what conditions are required within tanks containing various types of fuels to produce combustible mixtures. However, this problem is so complicated by the practical considerations of air flows through the tanks, fuel sloshing and misting, fuel weathering, etc., that it is apparent that much more research is needed if we are to expect designers to reduce the probability of the existence of combustible vapours within fuel tanks. As things stand now, we must assume that under some flight conditions any tank containing any type of aviation fuel will contain explosive vapors and/or mists. This brings us to the question, "How do the combustible vapors, when they occur, become ignited?"

There is still a very serious doubt as to whether or not lightning could have produced the ignition of the vapors in the tanks known to have exploded in the two accidents mentioned above. The result of thousands of lightning strikes to aircraft without serious damage, leads to considerable scepticism that such newspaper headlines as "Airliner Struck by Lightning — Explodes" are anything more than sensationalism. However, it has been established that the two events, lightning and the accident, occurred more or less simultaneously in both accidents, and it is also true that reasonably plausible theories can be advanced relating the two events. These facts alone should demand the most thorough-going investigation possible.

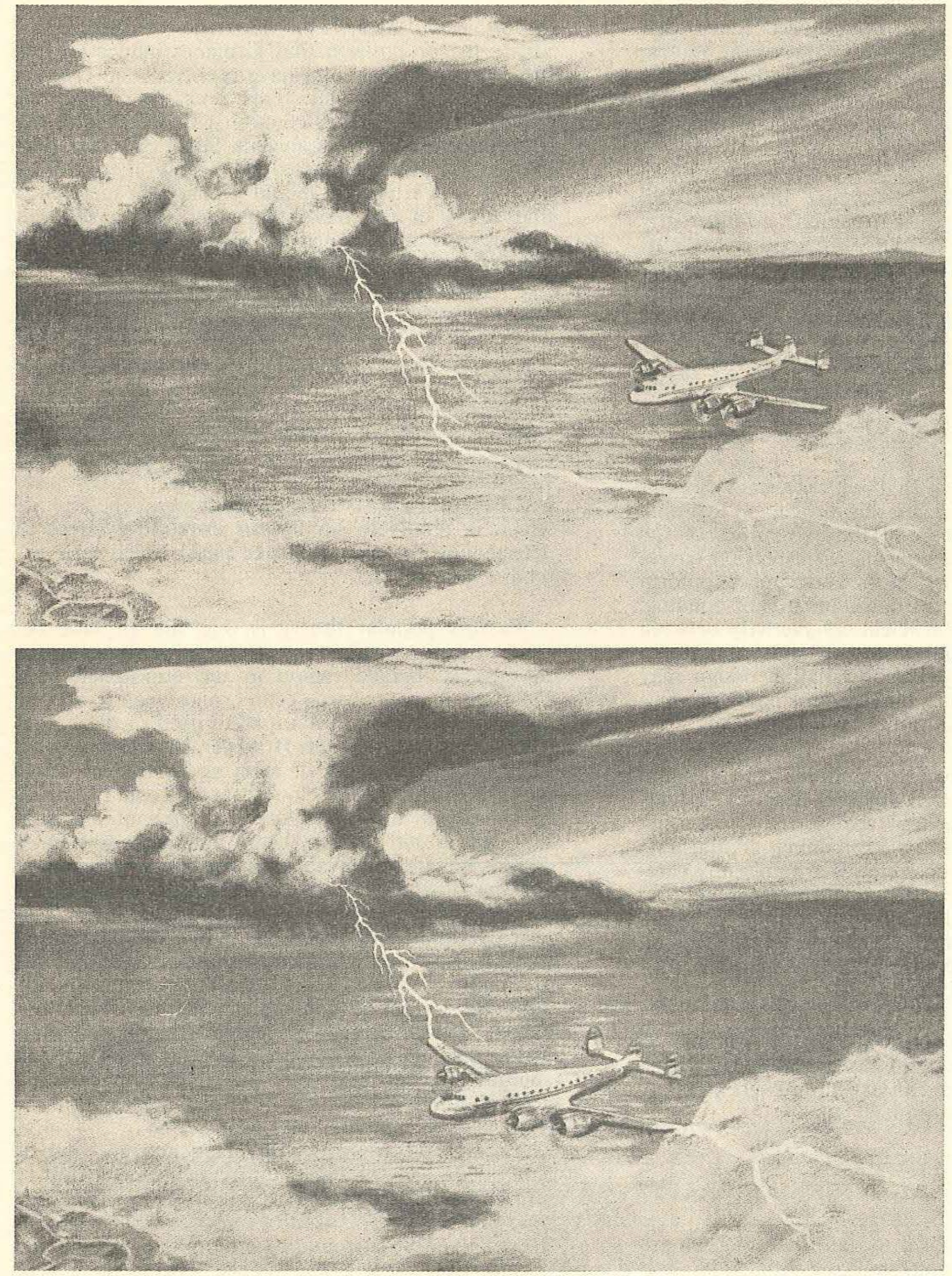


Figure 3

Why Does Lightning Strike Aircraft?

. . there have been reports of strikes very near but not actually to, aircraft in flight.

. . opinion most commonly held in authoritative circles is that airplanes which fly near thunderstorms will be struck only if they happen to pass near the natural stroke path at the time of its occurrence.

One thought which comes to mind is that, since the fuel tank vents are carrying vapors out into the airstream, perhaps lightning struck the vents, ignited the vapors, and the flame then propagated into the tank. However, in neither of the above accidents was there found the common pit marking of a lightning strike in the vicinity of the vents, at least not close enough to be within the zone which could contain flammable mixtures. Also, it has been found that only in climb does the vapor flow out of the vent in sufficient quantity to support combustion, and, if the airplane is climbing, the flame almost certainly would not propagate into the tube against the outflowing stream of vapors.

However, in recognition of the fact that fuel vents — because of their function — inherently seem to offer a possible source of ignition to lightning strikes, Lockheed recently participated in a study of the distribution of fuel/air vapors in the vicinity of vent exits. The new knowledge produced by this program provides all designers and operators information with regard to the zones in the vicinity of vent exits which should be protected from ignition sources. The study also suggests some possible areas for the development of design improvements.

Another possibility is that under certain circumstances, explained later in this article, a lightning bolt could be swept beyond the extremities of the airplane onto such components as inspection covers for fuel gauges or filler caps. These may conform in every respect to present day standards of bonding, but there may not be sufficient conductivity between the component and the primary structure to carry a **direct** lightning stroke. The installation design may be such that the primary high-current paths produce sparking inside the fuel tank.

Other possible sources of ignition which require further study include such items as induced currents in conductors within the tank spaces, and direct penetration of tanks or tubes containing combustible vapors. Some of these possibilities are presently carefully considered in design but more research is required to assure the adequacy of today's practices and standards. Also, methods of predicting areas on the airplane which are susceptible to lightning must be more precisely defined.

The National Aeronautics and Space Administration (NASA) has recognized the urgency of stepping up this research and we can expect answers to many of these questions as a result.

WHY DOES LIGHTNING STRIKE AIRCRAFT?

This is a question which to date has not been answered to everyone's complete satisfaction. The most credible answer is that the airplane is struck only when it happens to be in, or very near (within approx. one wing span of), the natural path of a lightning bolt.

Most scientists agree that this answer is, in fact, quite satisfactory and could reasonably account for all cases of aircraft lightning strikes where sufficient data exists and that have so far been investigated.

Nevertheless, there is no shortage of theories to justify the proposition that airplanes induce strokes to occur that would not have occurred had the aircraft not been present. This poses a conundrum closely akin to "Which-came-first-the-chicken-or-the egg?", and is almost as ancient. Some of these alternative theories are discussed below and others in Part Two of this article; it should perhaps be mentioned that many of the more plausible ones have been exhaustively investigated or will be investigated in the future in the interest of leaving no stone unturned.

The most prevalent theory is that the airplane, being a better conductor than the surrounding air, effectively shortens the distance between charge centers and thus triggers the discharge (stroke). Messrs. M. M. Newman and J. D. Robb, of Lightning and Transients Research Institute, have this to say in a recent report on the matter: "Little can be done in the immediate vicinity of an aircraft to control whether or not it is struck by lightning as the aircraft which is relatively small, can have little effect in determining the overall stroke path, which may extend several miles."

Another popular theory is that the airplane becomes charged either by friction or by passage through a charged region in the atmosphere, approaches another charge center, and when it is close enough, either induces a stroke to itself or discharges itself to the cloud center. However, the charge which the aircraft is capable of carrying is so small compared with that of the cloud that this could scarcely be considered an important factor. About the most that can be said for this theory is that the airplane's charge might conceivably be useful to an already existing stepped leader, exploring the vicinity for avenues of low resistance enroute to another destination. Newman and Robb say, "It should be noted that all discharges which cause damage to an aircraft are lightning strokes which terminate not on the aircraft but on the ground or on another cloud. So-called static discharges or general friction potentials which may be present on an aircraft from friction charging are not capable of damaging even thin aircraft aluminium."

Another theory, which is being actively investigated at present, is that the airplane leaves a trail of ionized particles behind as it passes from one charge toward another. This trail of ions, slightly more conductive than the surrounding atmosphere, is theorized to effectively shorten the distance between the charge centers and thus trigger a discharge. This theory provides a qualitative scheme of proper scale (a conductor of sufficient length) but it is questionable that such a trail can, in fact, be sustained more than a few feet behind the aircraft. It is also significant that strokes to the engine exhaust regions, which are theorized to be the principal sources of ionized gases, are rare compared to strokes to airplane noses, wing tips, and empennages.

CONCLUSION

Statistics of strokes to aircraft can be interpreted to indicate — or at least to hint — that aircraft may induce lightning strokes, but it is far from being generally accepted as fact. There is also data tending to refute this in that there have been reports of strokes very near, but not actually to, aircraft in flight.

The opinion most commonly held in authoritative circles is that airplanes which fly near thunderstorms will be struck only if they happen to pass near the natural stroke path at the time of its occurrence.

If we must operate aircraft in, or in the vicinity of, thunderstorms, then we must expect that they will be eligible for a strike throughout the period of time spent in critical areas. Such areas may be defined as being in the vicinity of thunderstorms and at about the freezing altitude. This aspect is discussed further in Part Two of this article.

In a study made some time ago, KLM Royal Dutch Airlines tabulated the strokes to each type of aircraft in their fleet, then concluded that: "These figures have no further meaning. They do not mean that a certain type of aircraft is more prone to lightning strokes than any other type of aircraft. It only means that there is a different system of operation of the planes, consequently, we have to be prepared for lightning damage if we operate planes on short runs like the CV-240 at the moment."

The problem then boils down to this: We must either stay away from lightning areas or we must do what we can to minimize the damage that could possibly result from lightning strikes. On some commercial flights, and quite frequently on some types of military missions, the first alternative is out of the question and, whether we like it or not we are forced to accept the second.

THE MISSING LINK

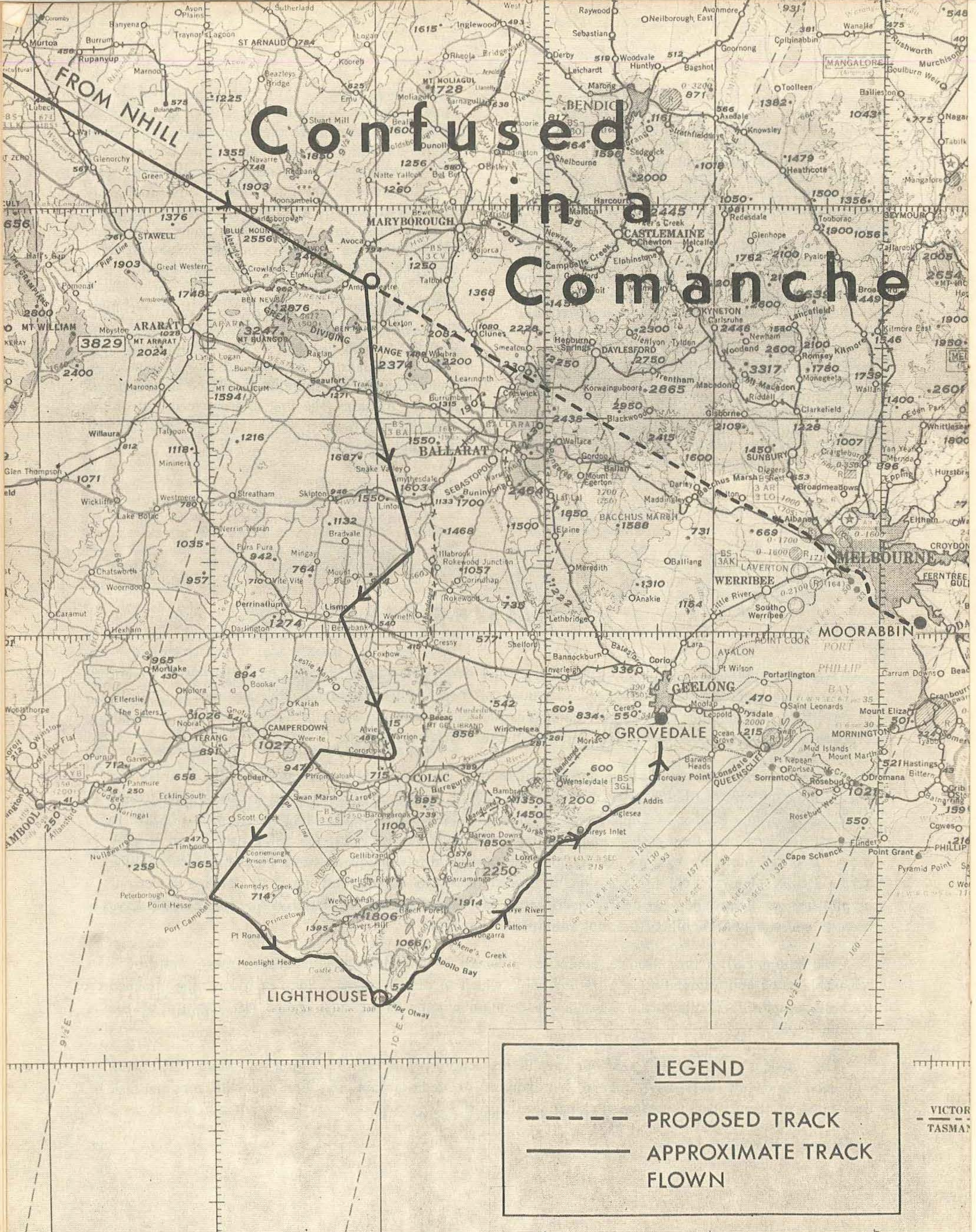
With the approach of summer, some charter and aerial work operators will be preparing to resume banner towing operations over selected areas near our popular beaches and holiday resorts. It is timely to recall that last summer a potentially dangerous incident occurred when a banner was involuntarily dropped while being towed by a light aircraft in the vicinity of Sydney.

Banner towing operations are not permitted to take place directly over densely populated areas and one purpose of this restriction is to minimize the hazard, to persons or property on the ground, which could result from a banner breaking loose. Even so, a falling banner could still be a significant hazard to third parties even over the lightly populated areas traversed between pick up point and beach display areas. It is not hard, for example, to imagine the possible dire consequences of a banner suddenly falling across a busy highway. On the occasion mentioned there was no resultant injury or damage to persons or property on the ground — **but there easily could have been** and, on the material side, there could have been a consequential liability for substantial civil damages.

The equipment, in this instance, comprised a length of manilla rope attached to the aircraft by a releasable catch and terminating in a trailing hook, which in turn, engaged a loop of nylon rope attached to the banner itself. The banner was lost when the manilla rope broke at a point just forward of the trailing hook.

The incident points to the need for careful inspection, before each operation, to ensure that towing equipment and tow lines have suffered no damage or deterioration and are adequate for the task demanded of them. Don't wait to find out the expensive way.

Confused in a Comanche



During a private flight from Nhill to Moorabbin, the pilot of a PA 24 became lost and flew almost 95 miles off track before his position was finally determined.

Departing from Nhill at 0900 hours, the flight proceeded uneventfully until after passing Stawell and beginning a descent to avoid an extensive layer of cloud. To steepen the descent the pilot made two descending orbits, the second at up to 60 degrees of bank and levelled out below the cloud at 2,500 feet on what he believed to be his original heading.

Clunes, midway along the railway between Ballarat and Maryborough was next check point, estimated at 1000 hours, and when at 0959 the aircraft passed over a small town on a railway line, it was assumed to be Clunes. From here, Ballarat should have been visible about ten miles to starboard and although the pilot was a little concerned when it could not be seen, he attributed it to the haze which was restricting visibility beneath the cloud. He was also unable to recognize a lake which now appeared on his port side but concluded that it could have been formed since his three year old map was published. In any event, he reasoned he must still be very close to his intended track and that he should soon sight Port Phillip Bay.

Visibility then seemed to be better to starboard and the pilot turned in this direction, expecting that it would help him pin-point his position. He flew this heading for some few minutes and then sighted a broad expanse of water in the distance. Assuming this to be Port Phillip Bay, he altered the heading to intersect what he thought was the light aircraft lane of entry between the Melbourne and the Laverton - Point Cook Control Zones. As he approached however, it became clear it was not Port Phillip Bay but a large lake that was entirely unknown to him.

At this stage the aircraft's position had been uncertain for some thirty minutes and the pilot now reported he was lost. Melbourne Operations immediately declared the Uncertainty Phase on the aircraft and set about trying to locate its position from the pilot's description of the landscape. This was made more difficult when radio communication deteriorated and messages had to be relayed by other aircraft in the area. Meanwhile the pilot had descended to 1000 feet above the terrain to avoid turbulence beneath the cloud and after being forced to divert to the west to clear a range of hills, resumed what he thought was a southerly heading. On reaching the coast some minutes later, he turned and flew eastwards and after another fifteen minutes, reported over a lighthouse. The aircraft was instructed to orbit while Melbourne Operations attempted to identify the lighthouse and from the pilot's description, one of the air traffic controllers on duty recognized it as the Cape Otway light. An airflash telephone call to the lighthouse confirmed the aircraft was circling there and Melbourne then instructed the pilot to proceed to Moorabbin via the coast and Geelong. When over Geelong about 30 minutes later however, the pilot became doubtful whether he could still reach Moorabbin with the required reserves and decided to land at Grovedale. The Uncertainty Phase was cancelled when he telephoned Melbourne Operations from Grovedale.

ANALYSIS

It is evident that the pilot's lack of experience was a contributing factor in this incident. He had held a Private Pilot Licence for less than two years and had logged only about 150 flying hours.

His navigational difficulties obviously began with the descent to avoid the cloud. Apart from the disadvantages, if not actual dangers, of a steep spiral descent in close proximity to clouds, the high rate of turn used would probably have toppled the gryo and disturbed the compass to the extent that an accurate heading, indication would not be immediately available when level flight was resumed. Visibility was hazy beneath the cloud and there was little outside the aircraft to indicate it was not on its previous heading. The pilot then mistook Trawalla on the Ballarat-Ararat section of the railway for Clunes and this both consolidated his belief that he was on track, and provided evidence for rationalizing the non-appearance of Ballarat and the unexpected sighting of the first lake. In assuming that the map was wrong, the pilot of course fell into the age-old error of inexperienced navigators. Since no fault could subsequently be found with the aircraft compass, it is not entirely clear why the pilot did not discern the error in his heading after emerging from the turns. The pilot believed he had resumed his original heading but stated later he was puzzled by the consistent error of 40 degrees in the headings flown while following the coast to Cape Otway and thence to Geelong. It therefore seems possible that the pilot had been maintaining track on the directional gyro and did not notice its setting was disturbed during the steep turns.

The poor visibility also played a significant part in this incident. The pilot was unable to recognise any landmarks through the haze ahead but conditions looked clearer to starboard. He turned in that direction, thinking this would take him in the general direction of Ballarat. Instead of approaching familiar landmarks however, the aircraft was now moving further away, and the chances of pin-pointing a position were becoming accordingly less. It has been found that when inexperienced pilots encounter map-reading difficulties they sometimes tend to fly where they think their track lies rather than rigidly adhere to a compass heading, and this tendency may have lead the pilot further astray once he had unwittingly turned from the track he knew. The fact that no changes of heading were logged and he was later uncertain of some of the headings flown again suggests that his attention to the compass was inadequate. Thus, when he first caught sight of Lake Corangamite, he had no hesitation in assuming it was Port Phillip Bay.

The aircraft's position had been uncertain for half an hour by the time the pilot called for assistance and the task demanded of the Search and Rescue Organization was a formidable one. Poor communication with the aircraft made it even worse. It was fortuitous that one of the officers on duty knew the Cape Otway area and was able to identify the lighthouse from the pilot's description.

COMMENT:

This incident bears out several rules which experience has shown to be vital to accurate VFR navigation:

1. Prepare an accurate flight plan making use of the meteorological information service which is provided for your assistance and safety.
2. Prepare your maps accurately marking the track to be flown. Drift lines and markings of distance/time intervals between obvious pin-points are an advantage. Study your route **before** commencing your flight.
3. Fly to your flight plan accurately, making alterations to headings and time intervals as required, but only upon **conclusive evidence** obtained through accurate map reading.
4. Mentally plan ahead of your flight plan, looking well ahead and to either side of your track for those features which your map tells you must be present. Know where you are on the map **all** the time.
5. Constantly check your directional gyro against compass heading. Remember to allow for deviation and that you must fly accurately to obtain an accurate heading indication from your compass.

If you follow these rules you should not get lost, but if during a flight you do become unsure of your position, keep to your flight plan until you can positively identify a pin-point. If your flight plan has been accurately calculated and you have flown accurate headings and air speeds, you should not be far from track.

Failure Forestalled

While taxying out for take-off at a capital city airport, the captain of a Viscount noticed a slight vibration similar to but somewhat less than what is usually felt when the brakes are applied towards the end of a landing run. The vibration was present despite the fact that the brakes were off, so the captain decided to conduct a further check by turning and taxying back towards the terminal. It then became evident that the port main wheels were dragging, although only slightly as little asymmetric power was required to compensate for it. The aircraft returned to the tarmac for the wheels to be checked by the maintenance staff.

When inspected, it was found that the port outer wheel was excessively hot but there was no sign of smoke or obvious damage. After it had been removed however, it was found that the wheel bearings had disintegrated and parts of the brake assembly had been damaged.

In his report on the incident, the captain emphasized that the warning symptoms which led him to make the additional taxying check were very slight indeed and that at no time did he suspect anything more serious than a binding brake. The pre-flight inspection of the wheel assemblies had revealed no evidence of the bearing failure and practically no drag was felt while taxying out to the end of the runway in use. Had the taxying distance been less, as would have been the case if another runway were being used, it is most likely that the bearing disintegration would have escaped detection. A complete failure might have then occurred either during the take-off or the subsequent landing.

By recognising an abnormal condition at an early stage, the captain avoided what could have become a serious hazard.

OVERSEAS ACCIDENTS IN BRIEF

In the June issue of our Digest, we published several brief summaries of aircraft accidents which had occurred in other parts of the world. Space limitations prevent the description of a large number of overseas accidents in detail, but there is no doubt that many contain valuable lessons that can be applied to operations in Australia. We now present a further selection of summaries and it is intended that these will become a regular feature of the Aviation Safety Digest.

Collision During Approach

After flying a conventional traffic pattern at an uncontrolled airport, a Cessna 210 turned on to final approach and collided with a Cessna 172 making a straight-in approach. The propeller of the 210 struck the rear fuselage of the 172 severing the tail assembly. The 172 crashed to the ground out of control, killing the pilot, but the 210 was able to continue to a safe landing. Although the pilots could have seen each other's aircraft while establishing their final approaches, they did not do so. However, had the pilot of the 172 conformed to the aerodrome traffic pattern, it would have given him ample time to see the other aircraft already in the circuit and make a safe approach to land behind it.

(C.A.B.)

Forgotten Undercarriages

Lockheed Electra

Preparing for a landing at the end of a night flight, the Electra crew completed the "descent" check list and reduced power. The landing gear warning horn sounded as the throttles were retarded but it was silenced for the descent. The crew then became engrossed in their respective duties and the captain continued the approach and landing with the undercarriage retracted. The crew could not subsequently recall if they had used the "before landing" check list.

(C.A.B.)

DC-8

While approaching for an en route landing in the course of a scheduled passenger flight, the crew of a DC-8 completed the "before landing" check list as far as the "gear extension and check" item. The aircraft was being flown by the co-pilot from the right hand seat and at this stage the crew's attention was diverted to other traffic in the circuit. Forgetting the undercarriage, the crew continued the approach. The warning horn sounded as power was reduced just before touch down and the undercarriage was immediately selected "down", but it had only begun to extend before the aircraft settled on to the runway and slid to a stop on the bottom of the fuselage.

(C.A.B.)

Comment

These two accidents, particularly that involving the DC8, amply illustrate the Department's view that on modern turbo-prop and turbo-jet aircraft, undercarriage warning systems actuated by throttle movement alone do not provide sufficient warning of an "unsafe to land" undercarriage position. As in the case of the DC8, the warning comes far too late for any remedial action.

The problem has been concerning the Department for some time and an Air Navigation Order is now being issued requiring that on certain aircraft types, the audible warning will operate not only when the throttles are retarded to the normal landing approach position, but also when the wing flaps are extended beyond the approach/climb configuration if the undercarriage is not down and locked.

Faulty Maintenance

Control Cables Reversed

After a Cessna 150 had taken off and climbed to about 100 feet, it banked sharply to port, the nose dropped and the aircraft crashed to the ground. The pilot was seriously injured and the aircraft destroyed. Investigation of the wreckage showed that the aileron cables were installed in the reverse sense. A 100 hourly inspection had been performed on the aircraft before the accident and the maintenance personnel responsible stated that they had found the aileron cables crossed and had corrected them. However, as there was no evidence of any aileron malfunction before the inspection, it was concluded that improper maintenance and inspection had been responsible for the accident.

(C.A.B.)

Comment

In Australia, all work performed on the flying control system of an aircraft must be subjected to two independent inspections before the aircraft is cleared for flight. ANO 105.1.0.2.8 sets out the Department's requirements in this regard. This accident emphasises again the extreme importance of applying these dual inspections with meticulous care.

Fatal Stall After Take-Off

Soon after becoming airborne on a take-off for a trans-Atlantic ferry flight, a Piper Twin Comanche climbed rapidly and assumed an increasingly steep nose-up attitude. It then stalled, and with very little forward speed, fell heavily to the ground in a level attitude. Both occupants were killed on impact.

Temporary long range fuel tanks had been fitted in the cabin in place of the rear seat. The investigation could find no record of inspection or approval for this installation and it was calculated that the centre of gravity at take-off was about four inches aft of the authorized rear limit. As well, the weight of the aircraft was 350 pounds in excess of the maximum overload permitted for a long distance ferry flight.

In this configuration, an uncontrollable nose pitch-up condition would occur unless the airspeed was allowed to build up well above normal and very close control maintained during the critical phases of take-off and climb.

(Ministry of Aviation)

Pilot Overcome by Carbon Monoxide

An hour after it had departed on a travel flight at 7,500 feet, a PA 24 was seen flying low at abnormally high speed. It then disintegrated in flight and the wreckage was scattered over half a mile. All five occupants were killed instantly.

Nothing was found to suggest any engine or control failure had occurred before the aircraft broke up, but an inspection of the cabin heating system disclosed a three-quarter inch hole had burned through the exhaust muffler wall into the heater muff. There were also several other breaks in the exhaust muffler around the spot welds. Post mortem examination of the pilot's body revealed a carbon monoxide saturation sufficient to cause unconsciousness at an altitude of 7,500 feet.

(C.A.B.)

Accidents in Turbulence

Fatal Take-Off

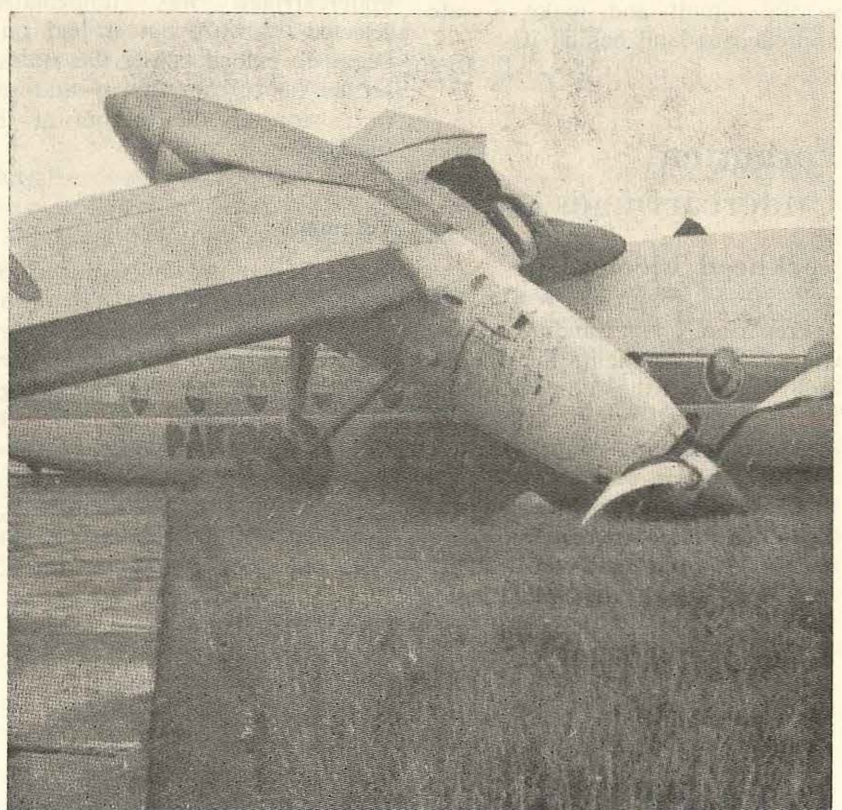
A Martin 404 began a take-off just as a thunderstorm was moving over the airport. Immediately after lifting off, the aircraft entered heavy rain, hail and severe turbulence. The aircraft was thrown about, dropping first the left then the right wing. It levelled out momentarily, then the left wing dropped again and struck the ground, causing the aircraft to cartwheel. Both pilots and five of the 43 occupants were fatally injured in the crash and subsequent fire. It was determined that the accident was caused by a loss of control in turbulence associated with a severe thunderstorm.

(C.A.B.)

Friendship Stalls on Final Approach

A line squall passed over a controlled airport just as a Fokker F27 was making a final approach to land at the conclusion of a scheduled flight. After crossing the runway threshold, the aircraft encountered severe gusts and visibility was reduced to almost zero. The aircraft stalled and dropped heavily on to the runway at a relatively slow forward speed. The impact sheared both wings off between the fuselage and the engine nacelles and the aircraft came to rest on one side of the runway with the fuselage intact. The passengers and crew were uninjured and were able to leave the aircraft without difficulty.

(Fokker Bulletin).



Aileron Controls Severed

While engaged on an extensive cross-country flight, the pilot of a Cessna 310 was warned of severe frontal conditions and thunderstorms across his intended route. Despite this the flight was continued and the aircraft later crashed in the area of frontal activity.

Examination of the wreckage showed the aircraft had struck the ground in a flat attitude with a very high vertical speed and little forward motion. Both tailplane surfaces had failed in upward bending and the outboard portions had separated in flight. The investigation found that manipulation of the controls could not fail the tailplane of a 310 without first failing the wings and it was concluded that the tail structure had failed when it encountered turbulence forces beyond its design strength.

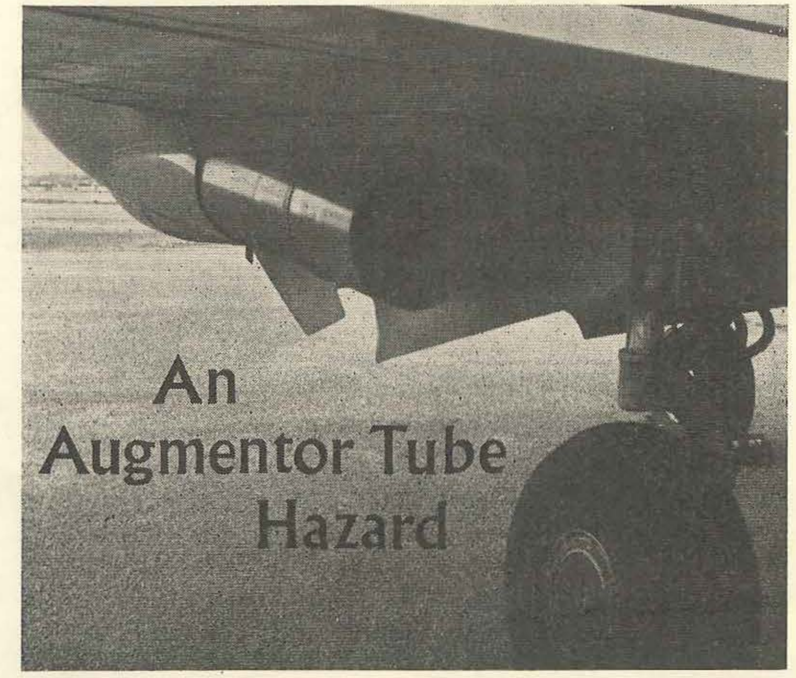
(C.A.B.)

Structural Failure in Flight

While flying at 1500 feet an Aeronca 11 suddenly encountered a brief but extremely severe area of turbulence, similar in character to vortex turbulence. Simultaneously, the pilot heard a noise in the airframe structure and lost all aileron control. He managed to guide the aircraft to a crash landing in the tops of some large fir trees, but was seriously injured when it crashed to the ground in a steep nose-down attitude.

Examination of the wreckage revealed that the aileron cable link plates above the cabin had pulled out, severing the aileron control system. The failure was attributed to turbulence-induced loads acting on the aileron surfaces.

(C.A.B.)



At Canberra recently, an engine of a Cessna 310 caught fire while it was being started for a flight to Cootamundra. A loud explosion inside the engine nacelle caused the cowlings to be blown open and the fire followed, but it was quickly extinguished by the fire crew and the damage was confined to the cowlings themselves.

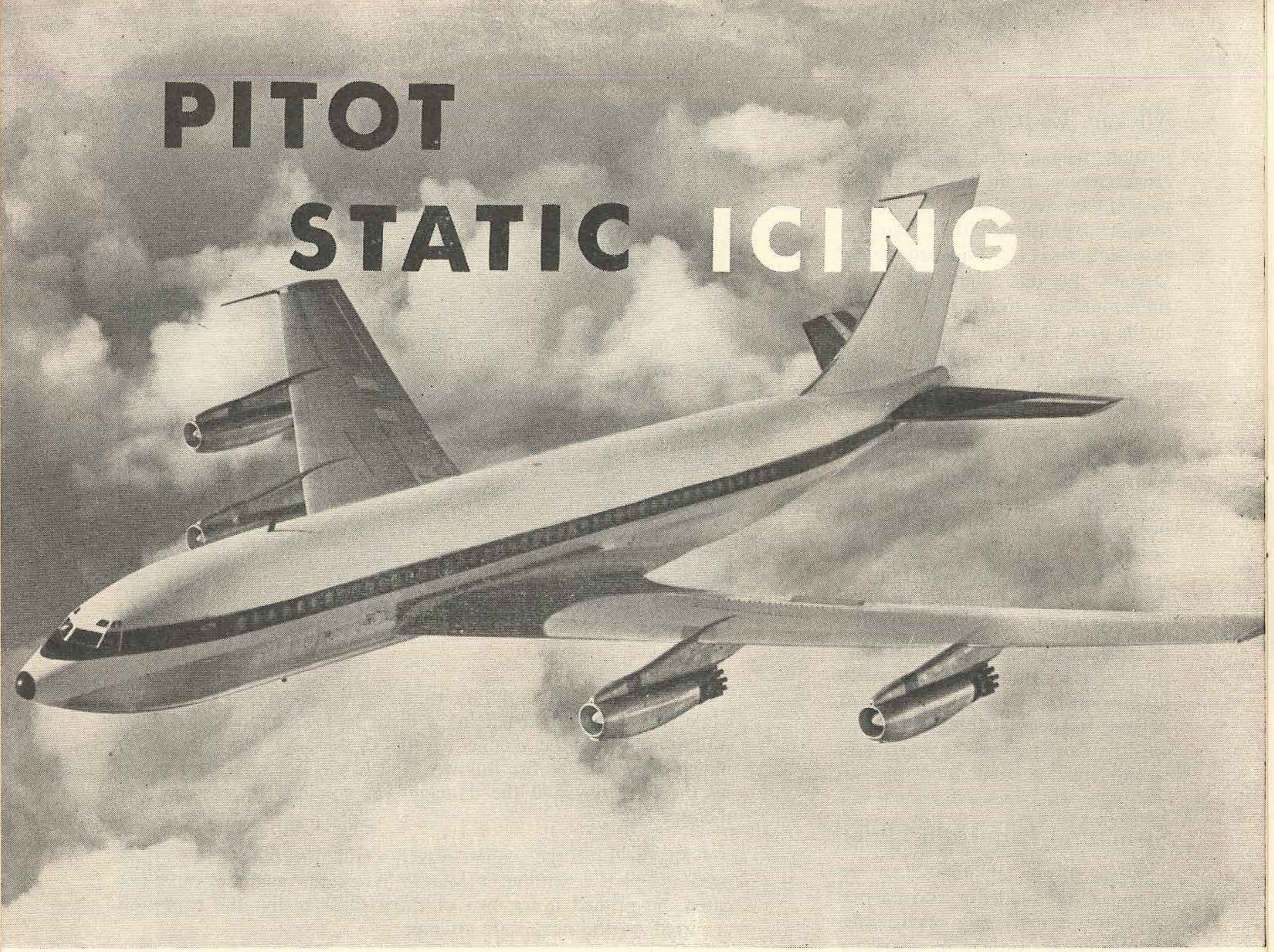
At the time the engine was hot and the pilot had at first tried to start it without priming. When the engine would not catch, he primed it for two or three seconds and the explosion occurred on the next start attempt.

Investigation revealed that the aircraft was standing tail into wind at the time and this fact, in combination with the hot and over-primed engine, had allowed the nacelle to fill with fuel vapour. When the engine fired, the exhaust flame in the entrance to the augmentor tubes ignited the vapour inside the nacelle, blowing out the cowlings and starting the fire.

The incident is by no means isolated. In December, 1960, the Digest reproduced a warning issued by the Beech Aircraft Corporation on the dangers of fire when starting augmentor tube equipped aircraft, and in 1961 the Cessna Aircraft Company sent a Service Letter to all operators of Model 310 aircraft setting out the precautions that should be taken against this possibility.

The problem is not confined to Cessna and Beech aircraft but applies equally to the starting of all aircraft that are fitted with augmentor tubes. Pilots can do much to eliminate the problem by at least observing the two golden rules of avoiding engine flooding, especially with a hot engine, and ensuring proper ventilation of the nacelle area by avoiding, as far as possible, downwind or excessive cross-wind start-ups.

PITOT STATIC ICING



In bulletins we have received recently from the Flight Safety Foundation in the United States there are three reports dealing with pilot-static icing on heavy turbo-jet transport aircraft. In two instances, the loss of an accurate airspeed indication created a difficult and hazardous situation. The pilot's accounts of these incidents provide some serious food for thought and emphasize the importance of cross-checking the flight instruments on jet aircraft. They should be of particular interest to pilots who are now converting to jets.

PITOT-HEAD ICING

After completing a night flight over a route on which considerable thunderstorm activity was encountered, the captain of a large jet gave the following report of his experience:

"During the climb I was completely engrossed in watching radar, heading, and airspeed. At about 28,500 feet we were between two large and very active storms that were some 25 miles apart, and we were in cloud or overhang associated with the storms. Engine heat was on and there was visible precipitation and static on the wind-shield. The cloud thinned, then the moon and stars became visible. I called for engine heat "off".

As expected, the ASI reading increased and I trimmed back on the autopilot. The speed continued to rise, and soon (perhaps 10 seconds) it indicated 365 knots, with VSI showing over 4,000 fpm climb, and a very high Mach reading. There was slight turbulence and my immediate thought was updraft associated with the storms. I pointed this out to the flight engineer and called for 89 per cent High Pressure Compressor R.P.M., and then asked for the copilot's airspeed reading. He reported 185 knots, falling.

On hearing this, I disengaged the autopilot, put the aircraft in level attitude and called for 95 per cent. H.P. Compressor R.P.M. Then we began a cockpit check! At this point I did not know what was wrong and what instruments to believe, but I did have confidence in the horizon. There was a lot of negative 'g' during the nose drop to level flight, but I must point out I was not conscious of a particularly nose-high attitude. In a few seconds the flight engineer found that the pitot-head heat switches were in the 'off' position. They were put 'on' and in no time the panel returned to normal and my ASI was reading 220 knots or thereabouts. The height loss was 1500 feet.

Later, when everything was back to normal, I began to wonder if this might have happened to those aircraft involved in loss-of-control incidents. The following would seem to me to be pertinent:

1. In my own particular incident, assuming the copilot's ASI to be correct (not necessarily true), it would only have taken a moderate amount of turbulence or a turn to bring on a low-speed stall.
2. How do you recover from a stall at night and in cloud without ASI?
3. What are the likely manoeuvres to be expected in such a recovery?"

STATIC PORT ICING

The airline jet had been cruising at 37,000 feet for several hours, with an outside air temperature of minus 50°C. Descent was started towards an airport where ground temperature was +30°C. Everything was normal at first, but at about 18,000 feet the aircraft entered moderate rain which continued down to 6,000 feet. At about 10,000 feet both the captain's and copilot's altimeters and rate-of-climb indicators began to fluctuate, and at first the crew thought it was caused by the rain. However, the fluctuations continued even after the aircraft had emerged into the clear again, and the crew contacted their company by radio to request that the fuselage be checked for ice, especially around the static ports, as soon as the aircraft arrived. It was found that even though the aircraft had been flown in temperatures of +20°C. for five or six minutes and the ground temperature was +30°C., the aircraft still had ice on the fuselage, though the static ports had cleared.

In relating this experience, the captain wrote:

"What we had was a very cold-soaked aircraft descending through rain which immediately froze on contact with the skin of the aircraft. We have had this to contend with in runback on the wing in the past, and it remains a problem when using wing heat.

"Since this experience", the captain added, "I've advocated heating the area around the static ports to prevent such a situation occurring. With the jet, the icing problem has been cut to a minimum in the areas of flight where in the past we had our greatest exposure. But the incident just mentioned is one that has come about with the jet. In fact, in over four years of jet experience, it was the only time I have seen icing become a problem and it was where you'd least expect it . . . in the tropics!"

ICE DISTURBS AIRFLOW OVER STATIC PORTS

The jet flight departed at night in extremely cold but clear weather conditions. The takeoff weight was just under 290,000 lbs., and the critical speeds had been computed as V_1-132 knots. V_R-149 knots and V_2-162 knots. The captain was flying the aircraft from the left hand seat and the story is told in his own words:

"Power was set on the brakes. The strong cross-wind took some of my attention, but nevertheless it appeared to me that it took longer than normal to reach V_1 speed, and I took a quick glance at the power instruments to check that power output was normal.

When we became airborne, I was surprised to see that we had used more runway than I had anticipated. I climbed out maintaining a pitch attitude of 10° nose-up. When I looked at the airspeed again, I was surprised to see that we only had 160 knots. Normally the aircraft should have accelerated to 175 by that time. What was more surprising was that the rate of climb was unsteady, fluctuating from 2000 ft./min. climb down to zero and then up again. It went through my mind that there probably was turbulence due to the strong wind, but I began to feel a bit unhappy. Nevertheless, I lowered the nose a bit to increase the airspeed and quickly verified pitch attitude on the standby horizon. The speed increased to 170 and by that time we had reached the noise abatement height of 700 feet, so I reduced power, but by then I began to realize something was really wrong so I put power back on again.

I looked outside once more to verify pitch attitude and checked the horizons. By that time I saw that we were lower than we should be and climbing rather flatly, so I pulled the nose up, but the airspeed indication of 170 made me put it down again. The vertical speed still fluctuated and the rate of altitude increase on the altimeter seemed much less than it should be. At 1800 feet I asked for flaps up when the speed showed 185/190 knots. Afterwards this may seem to have been a questionable decision, but lots of things went through my mind including the accidental lowering of full flaps during the take-off.

We had been instructed to turn left at 3000 feet and report, and when my altimeter indicated only 2000 feet the co-pilot to my surprise reported 3000 feet. I turned left more or less instinctively, but I later realized that I had done so to proceed towards the well-lighted city to keep visual reference since by that time the indications of the pressure instruments were so confusing. For instance, when the captain's rate of climb showed 2000 ft./min. up, the co-pilot's showed 2000 ft./min. down.

I thought of landing straight away, but the high gross weight and strong cross-wind stopped me from doing so. We proceeded east, climbing at 300 IAS on the captain's instrument. By that time there was a constant difference of 1500 feet between the captain's and the co-pilot's altimeter.

Then something even more disconcerting happened: there was a funny feeling on the elevator control. I felt repeated trim changes and then I saw that the pitch trim compensator had extended almost to maximum. At that time I also noted there was a big difference between the Mach - meters; the captain's indicating Mach 0.75, but the co-pilot's indicating Mach 0.84 as near as I could see. The co-pilot's airspeed showed 20 knots higher than the captain's ASI. We tried alternate static on both the captain's and the co-pilot's instruments. This made the indications of the captain's and the co-pilot's the same, but I knew they were both wrong since the vertical speed indicators fluctuated and the airspeed and Mach figures did not correspond with the power settings.

We levelled off at 31,000 feet (on the co-pilot's altimeter) and I engaged the autopilot, setting power according to the graphs. We flew this way for a while, having removed the pitch trim by override and pulling the circuit breakers. The autopilot could not be used in the altitude hold mode. We had asked ATC to provide additional vertical separation. After about one hour 15 minutes the indications began to return to normal, and after one and a half hours everything was O.K. again.

There is no doubt that this could have been a very dangerous thing if the weather had not been so perfect. I believe that what really saved us was the fact that I was sure right from the beginning that the horizons were O.K., which I was able to verify by simply looking outside, being over a well-lighted area. It is hard to put into words how confused one can feel taking off at night if the airspeed is much lower than one expects and an indication of a descent on the vertical speed indicator is seen together with an insufficient increase in altitude on the altimeter while power and pitch attitude are O.K. In this case my thoughts turned to horizon failure at first, and it is hard to say what I might have done if I had not had visual reference. This incident could have some bearing on a few unexplained crashes soon after a night take-off".

Investigation of this incident revealed that prior to departure, the aircraft cabin had been heated from an external source after the cabin water tanks had been re-filled with relatively cold water. When this water warmed up and expanded, some of it spilled out through the tank vents while the aircraft was still on the ground. The vent of the forward water tank is located almost perpendicularly above the static openings on the port side of the fuselage, and as the outside air temperature was minus 20°C, the overflow froze as it ran down the fuselage, forming ice ridges near the static ports. In flight, these ridges created eddies in the airflow, causing pressure fluctuations in the static lines system. It was also found that the manufacturer had previously recommended re-locating the static vent openings on this type of aircraft, but this had not been implemented.

OUT OF FUEL!

Not long ago, the pilot of a PA 24 was forced to make a wheels up landing in a paddock when fuel became exhausted only five miles short of the destination. The aircraft had just completed an extensive all-day charter trip from Moree, N.S.W., and after disembarking his passengers at Wellington late in the day, the pilot was making a 15 minute ferry flight back to his base at Dubbo Airport.

On the morning of the flight, the pilot carried out a daily inspection of the aircraft but omitted to remove the fuel tank caps to make a physical check of the contents. The fuel gauges showed full on both tanks and having forgotten that he had not refuelled since making a 30 minute flight two days before, he set out with the impression that the aircraft had its full fuel endurance of 240 minutes.

Towards the end of the day's flying, the fuel gauges were indicating abnormally low and although the pilot began to be doubtful of the endurance, he still failed to recall the previous flight. One tank in fact became exhausted shortly before reaching Wellington, and after landing and disembarking his passengers, he thought seriously of remaining there for the night. Nevertheless, on the basis of his flying times throughout the day, he reasoned that he **must** have sufficient fuel to safely reach Dubbo. Darkness was approaching so without waiting to inspect the level in the tanks, he departed for the 15 minute flight to his base.

Evidently the pilot was not completely satisfied for his mind continued to dwell on the fuel situation, and only a few miles short of Dubbo he suddenly recollected the earlier flight. But it was already too late. Almost immediately afterwards the fuel pressure gauges fell to zero and the engine failed.

In the gathering dusk, the pilot selected a field and lowered the undercarriage for landing, but late in his approach a power line appeared across the flight path. He retracted the undercarriage in the hope of clearing the wires but lack of airspeed forced him to dive below them and make a wheels-up landing.

COMMENT

This accident occurred because the pilot did not ensure that his aircraft was carrying sufficient fuel. His failure in this respect was a contravention of Air Navigation Regulation 225(1)(d). The most surprising feature of the accident was the pilot's extensive experience, and the fact that he had previously enjoyed the reputation for taking pride in the conduct of his flights. It is difficult to understand how a professional pilot could take a chance of this nature. Nevertheless, it clearly demonstrates that no amount of experience or ability can justify **taking anything** for granted in flying.

My thoughts for
A SAFE FLIGHT

1. I am physically, mentally and aeronautically prepared for the flight involved, a flight which I know will be in keeping with safe and approved operating procedures.

2. I know the safe operating techniques of my aircraft, and I shall make every effort to assure that my aircraft is in a good state of airworthiness.

3. I know my own limitations.

4. I will maintain the highest degree of vigilance throughout the conduct of my flight, being always mindful of the risk to human lives and property while I am at the controls.

5. I know the performance capabilities and limitations of my aircraft and have studied and reviewed all applicable emergency procedures to the extent that I can perform them under the pressure of any emergency.

6. I have a thorough understanding of existing weather conditions in my area of operation, and I have given considerable thought to alternative actions should there be an unexpected change in the weather conditions while I am airborne.

7. I will stay "ahead of my aircraft" and be in control of every phase of the flight.

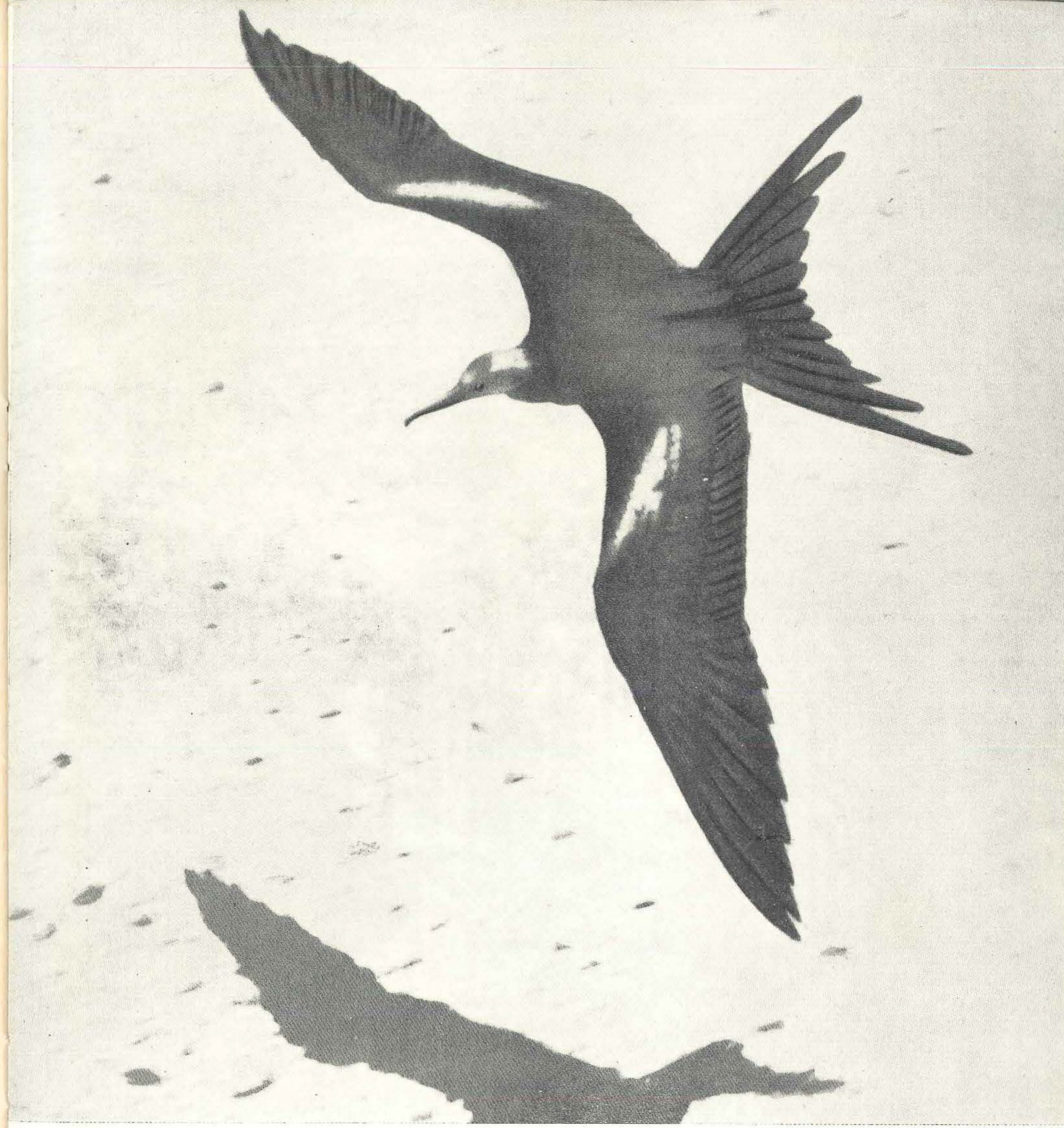
8. I will make a precautionary landing as soon as possible when any condition or occurrence causes me to deem it inadvisable to continue my flight. Unfavourable weather conditions, unfavourable wind conditions, a fuel state lower than that consistent with safe flight planning, a condition or discrepancy in my aircraft or powerplant that I do not understand, shall be predetermined conditions for discontinuing the flight.

9. I will always keep in mind that the flight does not end until the aircraft has been brought to a stop and the engine(s) shut down.

10. I will make appropriate notes and discuss with appropriate persons any mistakes or errors in judgment pertaining to my flight even though they may have been unobserved by others. This action may benefit other pilots or disclose an area for improvement in my piloting ability.

With all this thinking to do to stay alive why bother to fly?

Civil Aeronautics Board
Bureau of Safety.



LOW FLYING . . . .

The Frigate bird has a body the size of a chicken — but a wing span of seven feet. These wings can easily get caught in bushes and trees. When that happens, he's had it. For this reason the Frigate bird never flies low except when on operations — in search of food.