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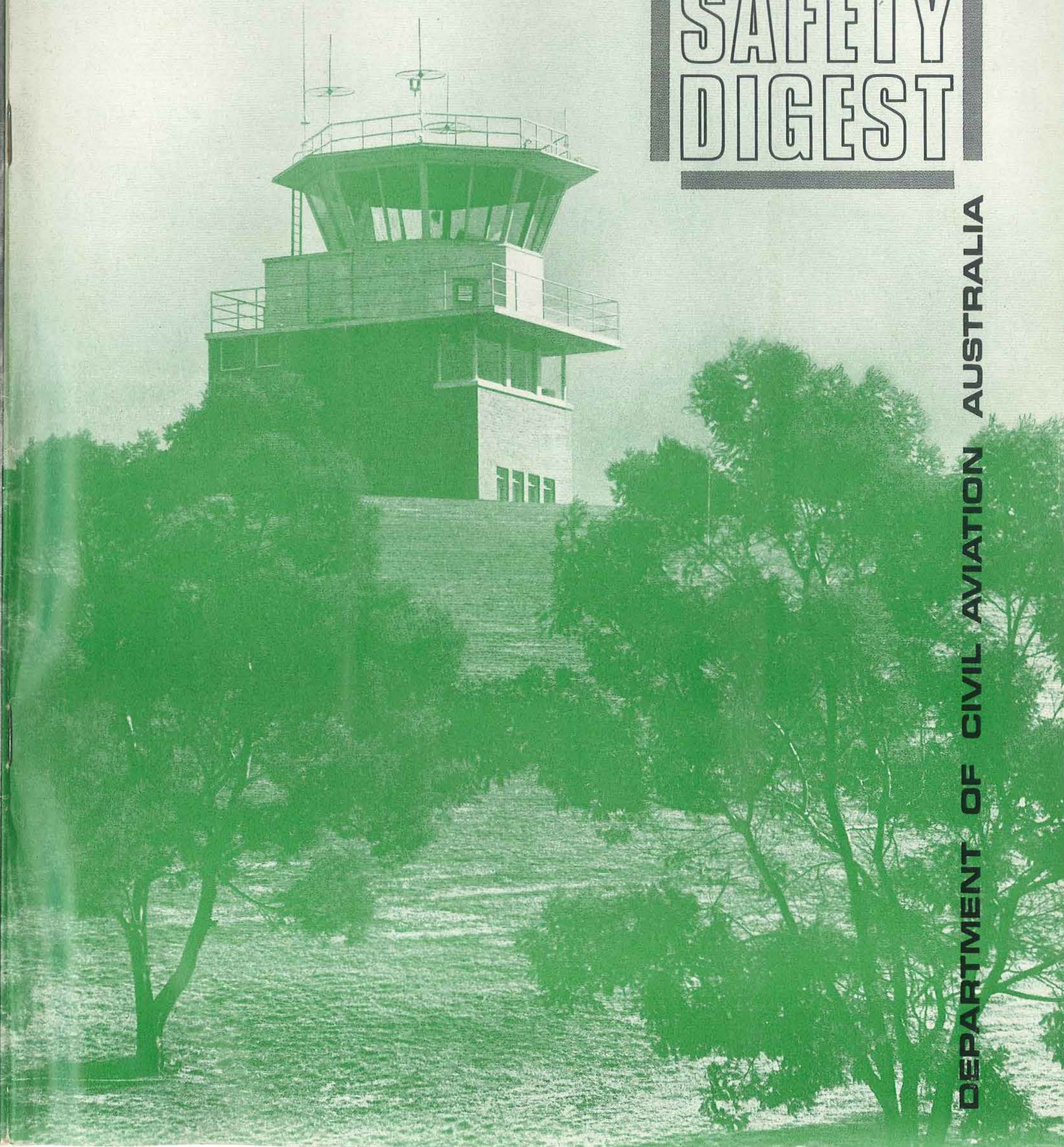
AVIATION SAFETY DIGEST



DEPARTMENT OF CIVIL AVIATION AUSTRALIA

elsewhere. At 1400 hours, the time by which the aircraft's fuel would have expired, the Distress Phase was declared and an aerial search for the missing aircraft was begun from Bankstown, using six aircraft. Shortly after 1600 hours, the pilot of a Cessna 337 sighted the burnt-out wreckage of the missing aircraft close to the top of a heavily-timbered ridge in mountainous country, twenty miles south-west of Katoomba.

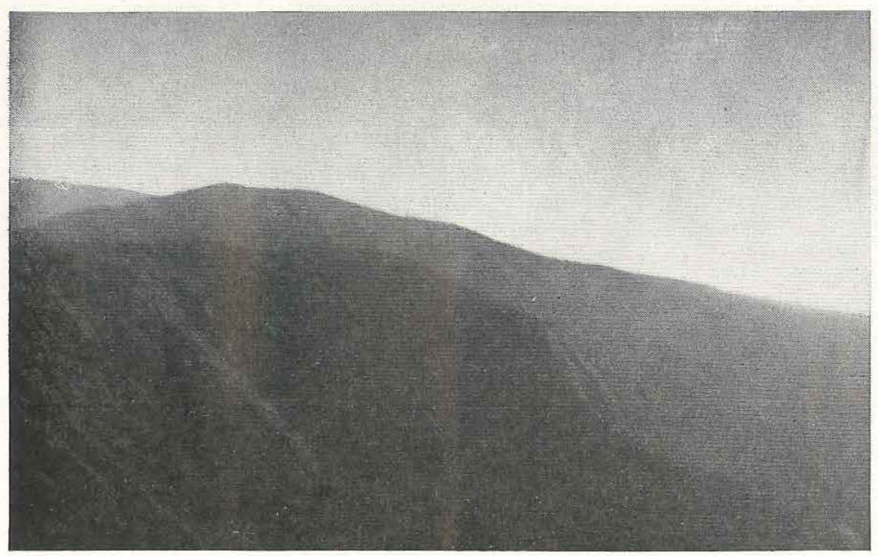
* * *

The site of the crash proved to be in such rugged and inaccessible country that the investigation team were able to reach the wreckage only by winch from a hovering helicopter. Examination of the site showed that the aircraft had struck the steep-sided timbered ridge, 75 feet below its crest, while flying level on a south-westerly heading. The height of the ridge at this point is 3,650 feet above sea level. The aircraft was totally destroyed by impact and the fire which followed, and the pilot was killed instantly. Examination of the wreckage disclosed no evidence of any defect or malfunction which could have contributed to the accident, and the intensity of the fire showed that the aircraft would have had ample fuel on board for continuing the flight.

The pilot, who held a private licence, had accumulated 180 hours' experience in the 19 months that he had been flying. He was regarded by his flying associates, including the flying instructors with whom he had trained, as reserved in his approach to flying and reluctant to take risks. He had made many similar flights to Lake Cargelligo during the previous months and on a number of occasions he had diverted or terminated his flight at alternative aerodromes because of what he considered was adverse weather over the ranges. He had also told his flying associates that he would not "press on" into adverse weather. He had explained that there was no urgency for him to complete his flights to Lake Cargelligo by any particular time and he was prepared to wait for any adverse weather to clear. From his remark to the tarmac attendant before departing on the day of the accident, it is evident that the pilot was well aware that there was cloud on the ranges on this occasion. There was nothing to indicate however that there was any greater urgency for him to get through to Lake Cargelligo on this particular flight than on any previous occasion.

The actual weather situation on the morning of the accident was influenced by a southerly stream above 2,000 feet, with light winds below this level. The stream had backed slightly to the south-east as the morning progressed, and as a result there was a well broken cloud base at about 1,500 feet in the Bankstown area. The cloud base rose and thickened progressively towards the ranges for about 50 miles to the west of Bankstown, where the crests of the ranges above the 4,000 feet level were in cloud for most of the day. The cloud cover dispersed to the west of the ranges and beyond the Bathurst area the sky was clear.

Although there was no eye-witness evidence from which the aircraft's flight path could be



The steep-sided ridge on which the aircraft crashed. Note how the height of the ridge falls sharply to the right of the picture.

One of the propeller blades detached from its hub at impact. Damage to the blades indicated that the propeller was rotating at speed when the aircraft crashed.

reconstructed, it is reasonable to assume that the flight progressed normally until the aircraft reached the foothills of the Dividing Range approximately 20 miles west of Bankstown. Here the general level of the terrain rises steeply to above 2,000 feet and it is probable that with the cloud base close to the tops of the ridges, the pilot would have diverted a few miles to the south of his track to follow the lower terrain of the Warragamba Reservoir area and the Cox's River Valley. It seems probable that, after following the Cox's River Valley and the Jenolan River Valley in the direction of the Jenolan Caves, the aircraft crossed the ridge on which the accident subsequently occurred but from the south-eastern side, and further to the north where the ridge is about 1,500 feet lower than at the accident site itself. It is evident from witness reports that the cloud base in this area at the time of the accident was about 3,750 feet above sea level. At this point therefore it must have been obvious to the pilot that the higher ridges a few miles further to the west were in cloud and that the possibility of his getting through was remote. It is apparent that the pilot then decided to turn back to Bankstown and made a 180 degree turn to the left in the valley immediately west of the ridge on which the aircraft subsequently crashed, in order to retrace his flight path down the Cox's River Valley and over the Warragamba Reservoir.

It is probable however, that at the point where the pilot attempted to recross the ridge, the cloud base was just above its crest, and to "squeeze through," the pilot would have been forced to fly very close, both to the base of the cloud and to the summit of the ridge.

Though it would seem unlikely, in view of his known respect for cloud, that the pilot would have become unintentionally caught in cloud with a consequent loss of visual reference, the possibility cannot be dismissed entirely. It has often been found that pilots with limited flying experience and little experience in realistically assessing weather conditions, can be oblivious to the fact that they are nearing the base of a cloud. They are of course aware of the cloud cover above them, but seem to have no idea of its vertical distance and go on climbing without realizing that they will suddenly be completely deprived of visual reference. It is thus possible that such a situation could have occurred in this instance.

Alternatively and perhaps more likely, in view of the indications that the aircraft was in straight and level flight at the moment of impact, it is possible that the pilot, flying very close to the base of the cloud, might have been deprived of forward visibility while still retaining visual reference in a downward direction. In these circumstances, the pilot might not have seen the ridge before the aircraft actually collided with the tree tops.

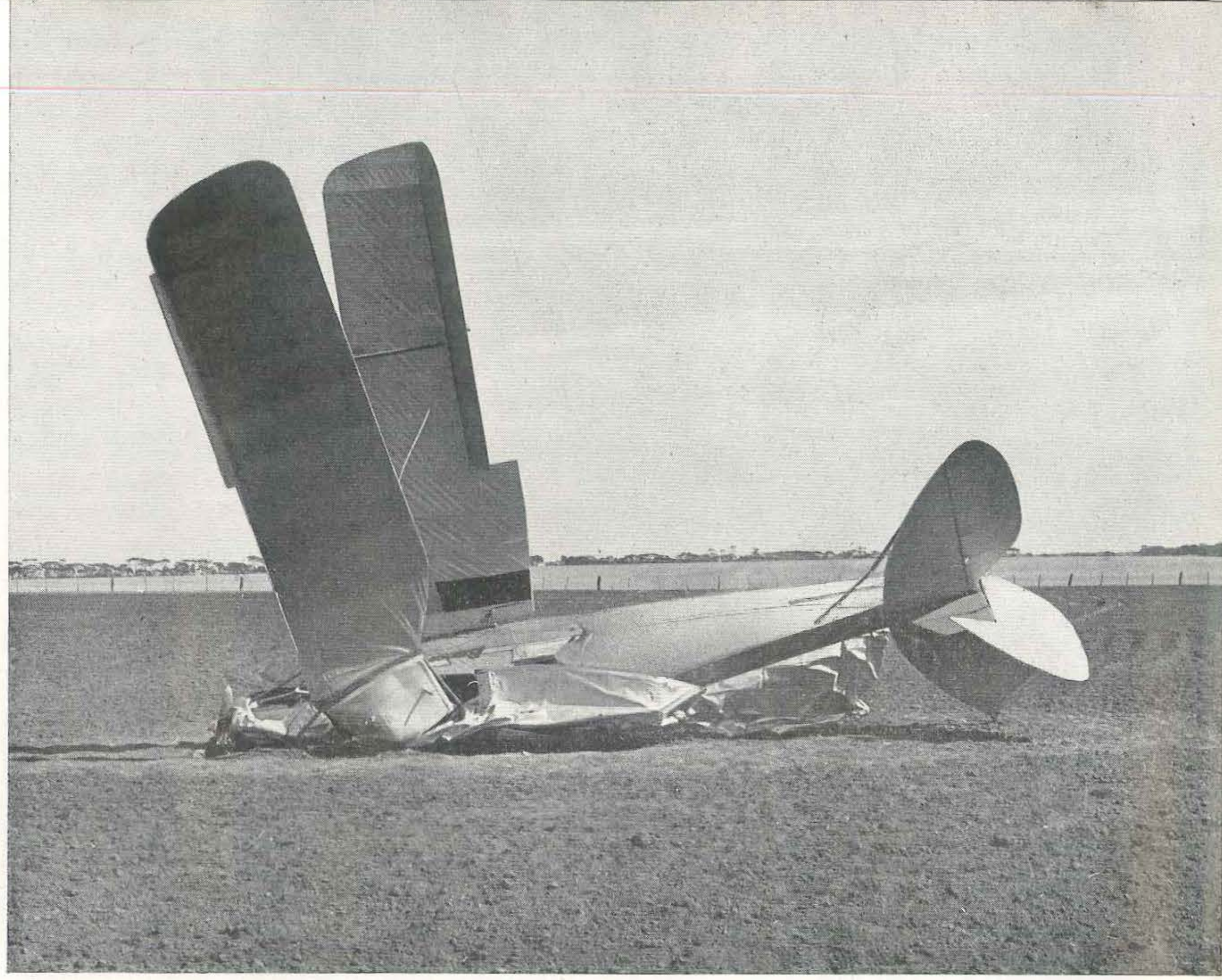
There is a third possibility which must be considered. After the pilot had turned back in the valley to the west of the ridge and was approaching the ridge again, but this time from its north-western side, it is possible that the aircraft's performance was affected by the considerable downdraught which would probably have formed in the lee of the ridge under the influence of the south-easterly wind. By the time the pilot realized that the aircraft would not clear the ridge, it might have been too late for him to take any avoiding action.

It is also possible that the pilot might have fallen victim to the "false horizon" phenomenon sometimes experienced when flying in mountainous terrain. Such an error could have contributed to the aircraft's failure to clear the ridge in the existing conditions.

The precise sequence of events that comprised the mechanics of this accident can only of course be a matter of conjecture. Whatever the actual circumstances were however, it is impossible to escape the conclusion that the accident would not have occurred if the pilot had not persisted in his attempt to continue the flight in what were obviously marginal conditions.

Cause

The probable cause of the accident was that the pilot proceeded into weather conditions in which visual flight with adequate terrain clearance could not be maintained.



SOME PEOPLE *NEVER* LEARN

(and what a way to treat a Tiger!)

THE pilot of this Tiger Moth, flying solo, was ferrying the aircraft from a town in northern Victoria to a relative's farming property in the same district, a distance of about 12 miles. At the property the pilot planned to clean the aircraft before flying it on to an authorised workshop for a 100-hourly inspection.

Taking off from the aerodrome, the pilot flew cross country at low level until he reached the vicinity of the property a few minutes later. Seeing one of his relatives driving a tractor on the farm, the pilot dived towards it, waving as he flew by at about 30 feet. Climbing again to clear two sets of power lines, the pilot then descended to a similar height to fly past another relative driving a second tractor in an adjoining paddock. Once again the pilot climbed, turned on to a reciprocal heading and dived back towards the tractor, descending this time to about 10 or 15 feet. After passing the tractor he maintained this very low altitude on the same heading, completely forgetting the presence of a secondary single wire power line 12 feet above the ground, which lay across his flight path.

Some 500 yards after passing the tractor, the pilot suddenly saw the wire immediately in front of the aircraft. Applying full power, he attempted to lift the aircraft over the wire, but the aircraft's starboard wheel became hooked. Losing speed rapidly as the wire stretched, the aircraft continued for about 150 feet, then, with nearly all the aircraft's momentum dissipated, the wire recoiled. The aircraft was spun horizontally through about 180 degrees, the port wing and nose dropped, and it struck the ground violently at a high rate of descent with almost no forward speed. As well as crumpling the port wing, dislodging the engine and breaking the propeller as shown in the photographs the whole airframe was buckled and distorted to the extent that it was a virtual write-off. Amazingly, the pilot escaped with only minor injuries.

Comment

Words almost fail us! Such comment as could be uttered about an accident like this has been said so many times before in the Digest that it hardly bears repetition (e.g., see "There's Danger Down Low," Aviation Safety Digest No. 56, May, 1968).

Yet there is one additional point that could profitably be drawn from this completely unnecessary accident. It is the fact that the pilot was entirely familiar with the property on which he crashed and knew very well where the power lines were! But despite this knowledge, in the excitement and exhilaration of his "beat up", he forgot about one line until it was too close to avoid it. Possibly, it was his very knowledge of the area that encouraged the pilot to indulge in his escapade, thinking no doubt, that the operation would be safe **because** he knew it. It is significant that in the first part of the "beat up," the pilot took care to lift the aircraft over two separate sets of power lines.

All of which shows once again that no amount of familiarity or local knowledge is proof against the dangers of yielding (usually on the spur of the moment), to the temptation to indulge in ostentatious exhibitions of low flying.

The pilot in this case can consider himself extremely fortunate to have survived—let alone to have escaped so lightly. He has lived to fly again but he has been taught a lesson he will not quickly forget. But of other would-be low flyers? We suggest they cash in **now** on someone else's experience before it is too late. The cost of gaining first hand experience of this sort might well prove to be a lot more than most people are prepared to pay. And besides—good Tiger Moths are hard to get these days!

Aeronautical Research and Air Safety

THE Digest does not engage in advertising, but the following information on the Department of Supply's Aeronautical Research Laboratories is being passed on to our readers because it is in the interests of air safety education — the purpose for which the Digest exists. With apologies to the ABC, we feel that it is "in a good cause"!

The Aeronautical Research Laboratories, at Fishermen's Bend, Victoria, are major contributors to the cause of air safety in Australia. This is not only because of their participation, as research consultants, in many of the air safety investigation tasks undertaken by the Department of Civil Aviation but also because of their day to day involvement in a wide field of general aeronautical research, including projects for the Services, for D.C.A. and for the Department of National Development.

Unfortunately, the work of the Aeronautical Research Laboratories is much less well known than it deserves to be amongst those segments of the aviation industry which would not normally have direct contact with the Laboratories. A series of Open Days, from 30th April to 2nd May, inclusive, will provide one opportunity to remedy this situation. New techniques and equipment developed by the Laboratories will be on display and exhibits will include the Ikara Anti-Submarine Weapon System, assessment of the safe life of aircraft structures, tests on Mirage aircraft, wind tunnel displays, new engine intakes and development of new materials for aircraft.

Persons interested in attending one of the Open Days may obtain an invitation by writing to:—

The Chief Superintendent,
Aeronautical Research Laboratories,
Box 4331, P.O. MELBOURNE. 3000
or by ringing 64 0251 (Melbourne Exchange) Extension 654.

The information contained in this article was originally published as an Advisory Circular by the Federal Aviation Agency in the United States of America. The Circular was prepared in collaboration with the United States National Severe Storms Laboratory which, over a four-year period, from 1964 to 1967 inclusive, carried out a

THUNDERSTORMS

programme of research on thunderstorms in the state of Oklahoma, U.S.A., an area noted for its severe storms. Because of the effects severe thunderstorms can have on the safety and efficiency of flight (see "BAC III Destroyed in Turbulence," Aviation Safety Digest No. 59, November, 1968), the Federal Aviation Agency, which had previously given its support to the research by the National Severe Storms Laboratory, requested the Laboratory's Director to provide an overall evaluation of what is now known about the problem. This resulting article discusses weather conditions to be expected in relation to radar returns obtained by ground based equipment of the United States Weather Bureau and is intended to give pilots an understanding of the radar weather information that is now available in the United States for flight planning and when actually en route. No firm rule can be given on avoiding thunderstorm cells by a certain number of miles; rather pilots must exercise good judgment based on knowledge of thunderstorm characteristics to accomplish their flight safely.

Because of difficulties associated with the collection of accurate and comprehensive flight data, and the time required to analyse and publish findings on the one hand and the urgency of the problem on the other, the information provided by the Laboratory necessarily includes preliminary findings which may have to be revised in the course of continuing studies.

RELATIONSHIP BETWEEN TURBULENCE AND ALTITUDE

Studies carried out by the National Severe Storms Laboratory on thunderstorms extending to 60,000 feet show that there is little variation in the intensity of turbulence with altitude.

RELATIONSHIP OF TURBULENCE AND RADAR ECHO INTENSITY

It has been found that the frequency and severity of turbulence in thunderstorms increases with the radar reflectivity of the storm cell. The radar reflectivity factor used in weather radar studies is a measure of the intensity of an echo from a storm target at a standard range. Pilots and air traffic specialists may be unfamiliar with this reflectivity factor, but it provides a logical basis for interpreting weather bureau radar displays and determining the degree of turbulence to be expected. For example, derived gust velocities exceeding 35 feet per second (classified as severe turbulence) are commonly encountered in storms whose maximum reflectivity is 10^4 or more. In storms whose peak intensity is about 10^3, gusts of between 20 and 35 feet per second (classified as moderate turbulence) are encountered approximately once in each ten nautical miles of flight.

TURBULENCE IN RELATION TO DISTANCE FROM A STORM CORE

Data obtained by the Laboratory indicates that the frequency and severity of turbulence encounters decrease slowly with distance from storm cores. Significantly, the data indicates that 20 miles from the centre of a severe storm core, moderate to severe turbulence is likely to be encountered only one fifth as often at any altitude, than in the core of a severe storm whose radar reflectivity factor exceeds 10^4. Furthermore, moderate to severe turbulence can be encountered at any altitude up to 10 miles from the centres of less severe storm cores with reflectivity factors of between 10^3 and 10^4. **Severe turbulence is often found in tenuous anvil cloud, 15 to 20 miles downwind from a severe storm core.** These findings support the meteorological reasoning that a storm cloud is but the visible portion of a turbulence system, whose up-draughts and downdraughts often extend beyond the storm itself.

TURBULENCE IN RELATION TO DISTANCE FROM THE EDGE OF A STORM

Severe turbulence may be encountered in clear air near an Oklahoma-type storm, and is more likely on the downwind side of the storm. At the edge of the cloud, the mixing of cloudy and clear air often produces strong temperature gradients associated with rapid variations in vertical velocity.

Tornadic activity can occur in a wide variety of positions relative to the strong radar echoes with which they are commonly associated, but in the United States the most intense and enduring tornadoes usually develop on the southern and western edges of severe storms, i.e., on the upwind side. Air rising in a tornado can contribute to a down-wind area of strong radar echoes, while a tornado itself is often associated only with a weak echo or may produce no echo at all. Echo hooks and appendages are useful qualitative indicators of tornado development but are by no means infallible guides.

Severe turbulence should be anticipated up to 20 miles from severe storms, which often have a well defined radar echo boundary. In the case of weaker storms, which sometimes have indefinite radar echo boundaries, this distance may be reduced to approximately ten miles. Used in this way therefore, airborne radar is a particularly useful aid for maintaining a safe distance from severe storms.

TURBULENCE ABOVE STORM TOPS

The limited amount of flight data which is available on this subject shows that there may be a relationship between turbulence above the tops of storms and the speed of winds in the upper troposphere. When the speed of the wind at the top of a storm exceeds 100 knots, significant turbulence may be experienced as much as 10,000 feet above the cloud top. This figure may be decreased by 1,000 feet for each ten knot reduction in wind speed. This consideration is especially important with clouds which reach beyond the height of the tropopause. In most cases with today's civil aircraft however, flight above severe thunderstorms is a somewhat academic consideration and the question will assume greater importance only as supersonic aircraft are introduced.

TURBULENCE BELOW THE BASE OF STORMS

Although there is a little evidence to show that the worst turbulence occurs at middle heights in storms, the turbulence beneath a storm is not to be under-estimated. This is especially true when the relative humidity is low in any air layer between the surface and fifteen thousand feet. In these circumstances, the lower altitudes may be characterised by strong outflowing winds and severe turbulence when thunderstorms are present. In such conditions the turbulence considerations applying to flight near storms at high altitudes apply also to flight at lower levels.

MAXIMUM HEIGHT OF STORM TOPS

Photogrammetric data obtained by the Laboratory indicates that the maximum height attained

by thunderstorm clouds in Oklahoma is approximately 63,000 feet. Such very tall storm tops have not been explored by direct means, but meteorological studies indicate that large hail and strong vertical draughts probably occur within a few thousand feet of the top of these isolated stratosphere-penetrating storms. It is important therefore that encounters with these very tall towers be avoided at all altitudes.

HAIL IN THUNDERSTORMS

The occurrence of hail is much more clearly indicated by the intensity of radar echoes than is turbulence. For this reason, avoiding damage from hail should always be associated with avoiding moderate and severe storms.

TEMPERATURE VARIATIONS NEAR THUNDERSTORMS

The greatest variations in temperature have been found to occur on the edge of thunderstorm clouds in a dry environment, and near tops of storms which reach into the tropopause. In these situations it has been found that temperature changes and turbulence are statistically associated. Temperature changes as great as 10°C per mile have been measured near severe storms, while temperature gradients of three to four degrees per mile are quite common.

RELATIONSHIP OF VISUAL APPEARANCE OF STORMS AND TURBULENCE

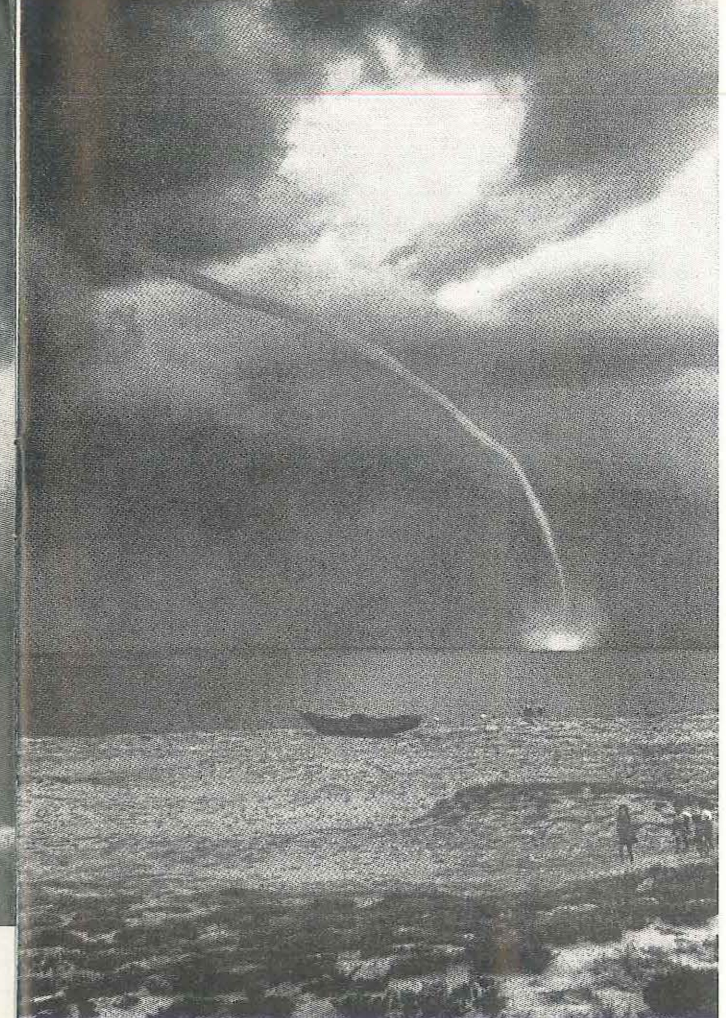
Numerous flights into thunderstorms made by the Laboratory indicate that there is no useful correlation between the appearance of a thunderstorm and the degree of turbulence and hail that exists within that storm.

PRECAUTIONS FOR SEVERE STORMS AND RAPID STORM DEVELOPMENT

During the development of a severe storm, radar echo intensities may grow by a factor of ten each minute, and cloud tops by 7,000 feet per minute. In these situations, no flight path through any area where severe storms are separated by less than 20 to 30 miles can be considered to be free from severe turbulence.

APPLICATION OF OKLAHOMA DATA TO OTHER AREAS

As already mentioned, Oklahoma is noted for its severe storms. A characteristic of the area is the relatively frequent occurrence of atmospheric stratification, marked by large moisture values in low levels, relative dryness in middle levels and strong wind shear. This stratification of the air's moisture content allows a very large degree of convective instability to exist until such time as a



rapid overturning of the air is triggered off by a suitable disturbance. In contrast to this situation, regions of the atmosphere which are either very dry or very moist to substantial heights cannot harbour great convective instability, and a more neutral thermal stratification is maintained, partly through a process of regular atmospheric overturning.

This greatly simplified comparison of atmospheric conditions in Oklahoma with those found elsewhere permits the following cautious generalisation from the experience gained during the Oklahoma studies:—

Desert Areas: In these regions, thunderstorms should be avoided on the same basis as described for Oklahoma. Non-storm turbulence can be expected more frequently over desert areas than elsewhere during daylight hours but in the vicinity of thunderstorms the turbulence considerations discussed above still prevail.

Tropical and Humid Climates: When the atmosphere is moist and only slightly unstable to a great height, towering clouds producing strong radar echoes may not contain vertical currents as powerful as those experienced in the storms in the United States. Lest pilots be lulled into a false sense of security however, it must be remembered that practically all areas in which thunderstorm development takes place occasionally produce a severe thunderstorm. For this reason, pilots operating in tropical and humid climates should be well informed on the general atmospheric conditions accompanying thunderstorm activity, to assist them to form a realistic assessment of the likely severity of these storms.

USE OF AIRBORNE RADAR

Airborne radar is a valuable aid for determining the location of storms but pilots should remember that it is intended to be used primarily for the purpose of *avoiding* storms while en route.

FURTHER ADVICE TO PILOTS

As more information becomes available from further weather radar research and actual thunderstorm penetrations by specially equipped aircraft, the United States Federal Aviation Agency intends to update and supplement the information published in their Advisory Circular. Through this intense research programme, the Federal Aviation Agency are attempting to provide their Air Traffic Control system with the capability to locate, identify and measure the intensity of turbulence associated with severe weather, so that accurate advice on the weather to be avoided can be supplied to pilots.

Application to Australian Conditions

There is good reason to believe that the factors affecting the association of turbulence with thunderstorms in the United States of America are equally applicable in Australia. In terminal areas meteorological and air traffic control ground based radars employ the reflectivity method of assessing turbulence in thunderstorms. Within ten miles of an airport ATC will close airspace affected by known turbulence, whilst in the remainder of a terminal area, including holding patterns, ATC clearances are devised to enable aircraft to avoid known turbulence areas by at least five miles up to the freezing level, and by 10 miles above that level. Within these latter areas, and beyond them, pilots may determine their own flight paths to avoid turbulence, and, in so doing, should pay due regard to the principles outlined in the preceding paragraphs. It must be remembered, however, that in controlled airspace any deviation from the current ATC clearance requires ATC concurrence.

HELICOPTER ENGINE OVERSPEEDING

In Papua, the pilot of a Bell 47G-3B-1 helicopter, engaged in a charter flight, made a slow circling descent at low power to inspect a proposed landing pad in a valley. After inspecting the pad from about 200 feet and deciding that it was unsuitable, the pilot applied power to continue the flight. The manifold pressure increased initially to about 20 inches, but then there was a loud bang followed by severe vibration, and the engine lost power. The rotor speed decayed and the helicopter descended into the dense jungle, struck two tall trees and crashed upside down in the undergrowth. The pilot and one passenger were seriously injured and a second passenger sustained minor injuries. Subsequent examination of the engine showed that the ends of the inlet valve guides were damaged. On the number two cylinder, the valve guide deformation had been sufficient to cause the inlet valve to jam. The damage was the result of hammering by the valve spring retaining collets, and was probably caused by the engine being oversped at some previous time.

In Queensland, a Bell 47G-2 helicopter was carrying out a survey flight involving numerous landings to take observations. After operating normally throughout the day, the aircraft landed in a clearing in timbered country late in the afternoon. The engine was not stopped during the few minutes the helicopter was on the ground and the pilot made a satisfactory pre-take-off check before taking off into the 15-20 knot wind. After climbing to about 300 feet, the pilot began a turn to the right to take up his heading, but the engine began to run roughly and lose power. Vibration then set in and the helicopter began to lose height. The pilot, realising that the only course open to him was to attempt a downwind landing in the clearing from which he had just departed, placed the helicopter in auto-rotation. He then saw that even flying downwind the helicopter would not reach the clearing in auto-rotation. Aware that the engine was still running, the pilot utilized the power available to "drag" the helicopter into the clearing and it touched down heavily. The aircraft was extensively damaged but the pilot and his passenger escaped without injury. Examination of the engine showed that the exhaust valve in the number five cylinder had broken off, severely damaging the piston, the inlet valve and the cylinder itself. The end of the valve guide exhibited impact marks of the valve spring retaining parts which indicated that the engine may have been oversped at some time. Further examination revealed that several inlet valve guides showed similar impact marks.

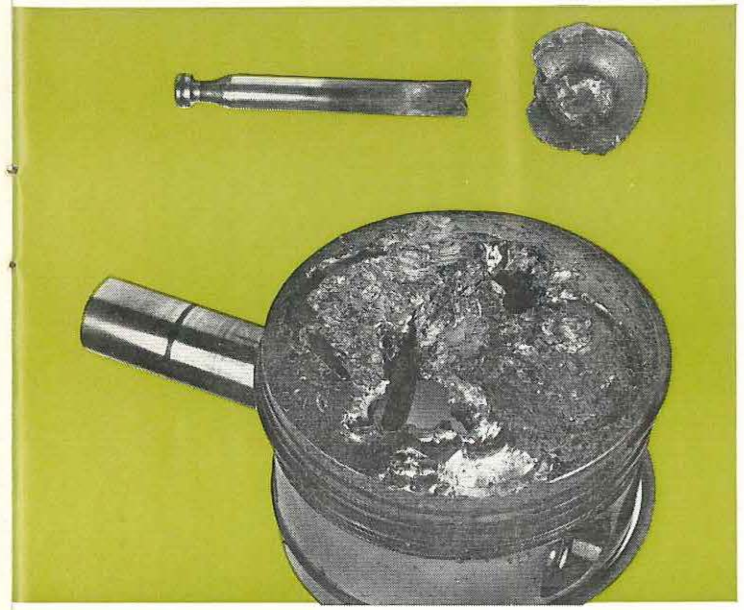
In Western Australia, a Bell 47G-3B-1 helicopter was making a geological survey flight in the Leopold Ranges carrying the pilot and two geologists. After completing the survey work for the day, the aircraft began the return flight to its base but whilst cruising at about 700 feet, the engine backfired and lost power. Almost immediately the aircraft began to lose height. Although over rugged terrain, the pilot selected the best available site for a forced landing and entered auto-rotation. The approach to the landing site was a difficult one, requiring a manoeuvre around the side of a hill to avoid a granite outcrop. The rate of descent increased in the lee of the hill and in an attempt to reach the landing area, the pilot was forced to "milk" the collective pitch. A flare initiated at about eight feet above the ground failed to regain sufficient rotor R.P.M. and a heavy landing resulted. The aircraft was substantially damaged but the pilot and two passengers were uninjured. Inspection of the engine showed that the number one inlet valve was jammed tight in its valve guide. The guide itself was heavily impacted on its outer end and the valve spring retaining washer and the collets had sustained damage. All other inlet valve guides with the exception of that in the No. 4 cylinder exhibited similar impact damage and three other inlet valves were tight in their guides. The nature of the damage was suggestive of the engine having been oversped at some time since the engine's last overhaul.

It was also learned that, some 20 operating hours before the accident, the engine had suffered a similar loss of power while hovering. An on-site investigation by a L.A.M.E. at that time had established that the No. 4 inlet valve was jammed in its guide. The No. 4 cylinder assembly was changed and, after a period of satisfactory test running, the helicopter was returned to service.

* * *

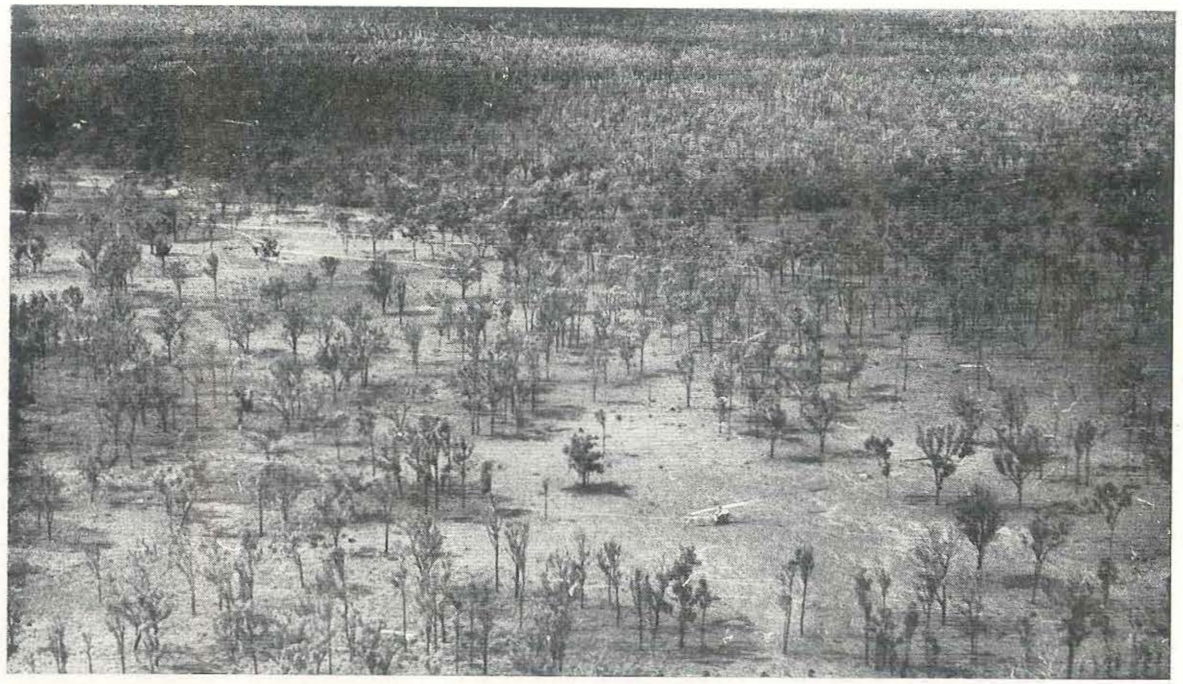
In addition to the engine damage revealed during the investigations of these three accidents, there has been a number of other instances in which similar, though less severe damage to valve guides and valve gear has been found during normal overhauls, in engines removed from Bell 47 series helicopters. The type of damage is caused by the lower side of the valve collets contacting and deforming the upper part of the guide, resulting in a loss of clearance between the valve and guide. As in two of the accidents described above, the condition may result in an inlet valve sticking open, causing backfiring and a complete loss of engine power. Other types of internal damage commonly found in engines that have deformed inlet guides include split spring retaining washers, partially sheared inlet valve collets, impact damage on the lower surfaces of valve rockers and bent push rods.

The broken exhaust valve and badly damaged piston, removed from the engine of the helicopter that force-landed in Queensland.



Damage of this type occurs when the inlet valve mechanism is forced past its normal range of travel in the valve opening direction. Assuming that the correct valve springs are fitted, the only known way in which this can occur in service is by over-speeding the engine. The engine manufacturers have in fact advised that they are not aware of any operating condition, other than an engine overspeed, that can cause inlet valve collets to strike and deform the ends of the valve guides.

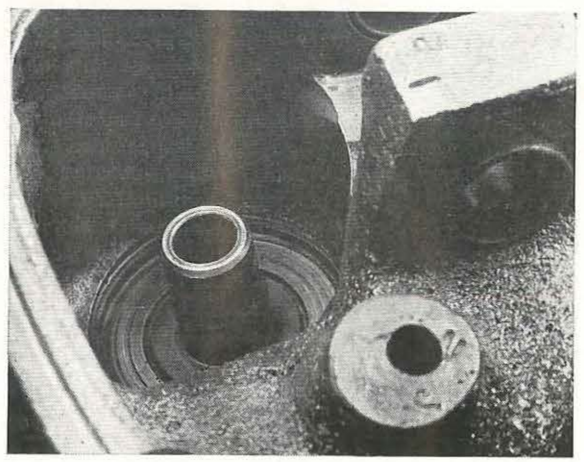
Most experienced helicopter pilots and ground engineers who take pride in their skill would no doubt vehemently deny that they could allow a helicopter engine to overspeed. With Bell 47 series helicopters however, there are several ways in which engine overspeeding can easily occur unintentionally. The first, and probably most likely, is when starting the engine with the throttle opened beyond the detent position. As the clutch is disengaged when the engine is being started, it is quite possible for the unloaded engine to overspeed before the clutch has time to fully engage. This can occur in such a short interval of time that if the pilot has not been closely watching the tachometer, he could easily miss any indication of overspeed. Another situation in which overspeeding can occur is during practice auto-rotations. Rotor overspeeds can occur in this sequence, and a power recovery initiated at a rotor overspeed of 50 r.p.m. would mean a corresponding engine overspeed of some 450 r.p.m. Other situations in which engine overspeeds can easily occur in Bell 47 series helicopters could include severe turbulence encounters, student training particularly during ground hovering sequences, leaving the controls unattended while the engine is running on the ground without first properly securing the throttle friction screw, and inattention to the collective/throttle controls during flight.



The site of the forced landing in Queensland. As is evident from the picture, the clearing in the timber was the only area in which there was any chance of making a successful forced landing.

Deterioration of the clutch as a result of glazing of the shoes or wear of the drum can usually be detected during clutch engagement, which requires an adequate co-efficient of friction between the drum and the shoes. The service condition of both these items is thus an important factor in achieving satisfactory clutch engagement. If the rotor r.p.m. lags during clutch engagement or if engine r.p.m. in excess of 2300 is required to maintain a steady increase in rotor r.p.m., the clutch should be removed at the first opportunity, the shoes de-glazed and the drum inspected for condition. Continuing to operate a glazed or worn clutch can only increase the possibility of clutch

Inlet valve guide damage typical of that found in the engines of the three helicopters referred to in this article. These two photographs, taken on different engines, show how the valve guide ends have been hammered and deformed by the valve retaining collets.



The site of the forced landing in Western Australia. The difficulty experienced by the pilot during his approach can be appreciated from the terrain in the background.

slippage with the likelihood of an engine overspeed. If a severe engine overspeed does occur, it is strongly recommended that, in addition to attention to the engine itself, the transmission be removed and the clutch and free wheeling unit be inspected for serviceability.

Although engine overspeeding may not always extensively damage the valve gear, it generally causes some damage to the valve guide ends. More important, overspeeding can have a destructive effect on the engine's dynamic counterweights, crankshaft lugs and their bushings, as well as connecting rods and bolts. It is vitally important therefore that a helicopter engine which has been subjected to a known or even suspected overspeed condition, in which the r.p.m. may have reached the limit prescribed by the manufacturers, should be given a very thorough inspection before being returned to service. This inspection should include dismantling the engine at least to the stage where the complete valve mechanism can be thoroughly checked. If any damage **is** found in the valve gear mechanisms, the engine should be further dismantled and inspected for damage to bearings, crankshaft counterweight assemblies (where fitted), connecting rod assemblies, etc. As recommended by the manufacturers, the engine should be fully dismantled and specified parts replaced, in the event of any overspeed that has exceeded the manufacturer's limit.

It should be obvious that it is of the first importance for pilots to report all cases of engine overspeed, however short the duration. It is worth noting that each valve mechanism operates more than 30 times per second when the manufacturer's overspeed limits are being exceeded. If the collets are striking the valve guides, serious damage can obviously occur very quickly. The fact that an engine may be capable of apparently satisfactory operation following an overspeed is no guarantee that it is free of damage, as inlet valve sticking caused by the reduction of clearance between a valve and its guide may not develop until some time after that condition occurs. Regardless of whether an overspeed has been observed or reported, any sign of backfiring by the engine should be treated with suspicion. Equally, any sign of excessive inlet valve travel in one cylinder should be sufficient cause for the other inlet valve mechanisms to be dismantled and inspected. If one valve mechanism has been subjected to overspeed then so have all the others. Two serious Australian helicopter accidents might have been avoided if the early danger signals described in this article had been correctly interpreted by the engineers and pilots concerned.

CHECK — or checkmate!

INITIALLY I learnt to fly primarily for the purpose of widening the horizons available to me. These horizons *have* been widened, and I have visited many places I would not otherwise have seen without the private licence that I obtained three years ago. But from the very first flying has become something more than a means of transport. It has become an important part of my life, and I still find it an ever-increasing challenge.

With some 450 hours' experience, I had become conservatively confident of my ability, yet I still respected and followed the procedures and lessons that were hammered into me during my initial training. Apart from the small digressions most of us have made at some time, I considered myself a methodical and safe pilot. Recently, however, I was involved in an incident which rudely awakened me and taught me a lesson I shall *always* remember. I relate it in the hope that others may benefit from my "experience" without finding themselves in a similar situation — minus the luck I had!

Late on a summer's afternoon I departed from the local aerodrome for a circuit in my Victa. I occupied the right hand seat and another private pilot, who had not flown the type for some considerable time, acted as pilot in command. The day was clear, with the sun low and very bright at the downwind end of the strip, and there was a 15-knot crosswind. After an uneventful circuit we landed, parked the aircraft at the downwind end of the strip and shut down. During the shut down my colleague began to switch the fuel cock off, but I told her to leave it on and I returned it to the on position myself (as I thought!). After alighting and assisting a passenger to board the aircraft, I took my place in the pilot's seat and started the engine again. The sun was extremely bright, so I put on my sunglasses to eliminate the glare, then ran through the full pre-take-off checks, including an engine run-up. On looking back, I distinctly remember checking the fuel cock physically, although I don't recall having checked the fuel pressure gauge. After taxi-ing on to the runway I lined up, re-checked the circuit area for traffic, then the windsock and started my take-off run.

After attaining a height of about 20 feet, suddenly and without any warning the engine stopped. Instinctively my hand shot to the fuel cock and, without thinking, I changed its position. I was now committed to a straight-in approach and my attention was fixed on the rough ground ahead at the end of the runway where I knew I would be in a matter of a very few seconds. How quickly height can be lost without power! Lady Luck was with me however, and the engine surged to life as I was rounding out within feet of the end of the strip. Actually the wheels did touch down right at the threshold, but the aircraft then climbed away safely. Later investigation showed that the starboard wheel had touched the ground some two feet inside the markers, passed within six inches of a marker tyre, and left the ground again another two feet further on.

The cause of this incident was clearly evident. On reviewing the circumstances which led to it, it was obvious that my pre-take-off checks left a lot to be desired. I now know most definitely the positions of the fuel cock and fully recognise the necessity of visually checking these positions as well as checking their "feel." How many of us have read of similar events which have had fatal results, but said, "But it couldn't happen to me"? Surely the obvious solution is the realisation that no one is infallible and that properly performed cockpit checks are essential if we wish, not only to continue flying, but to continue with life itself!

Comment

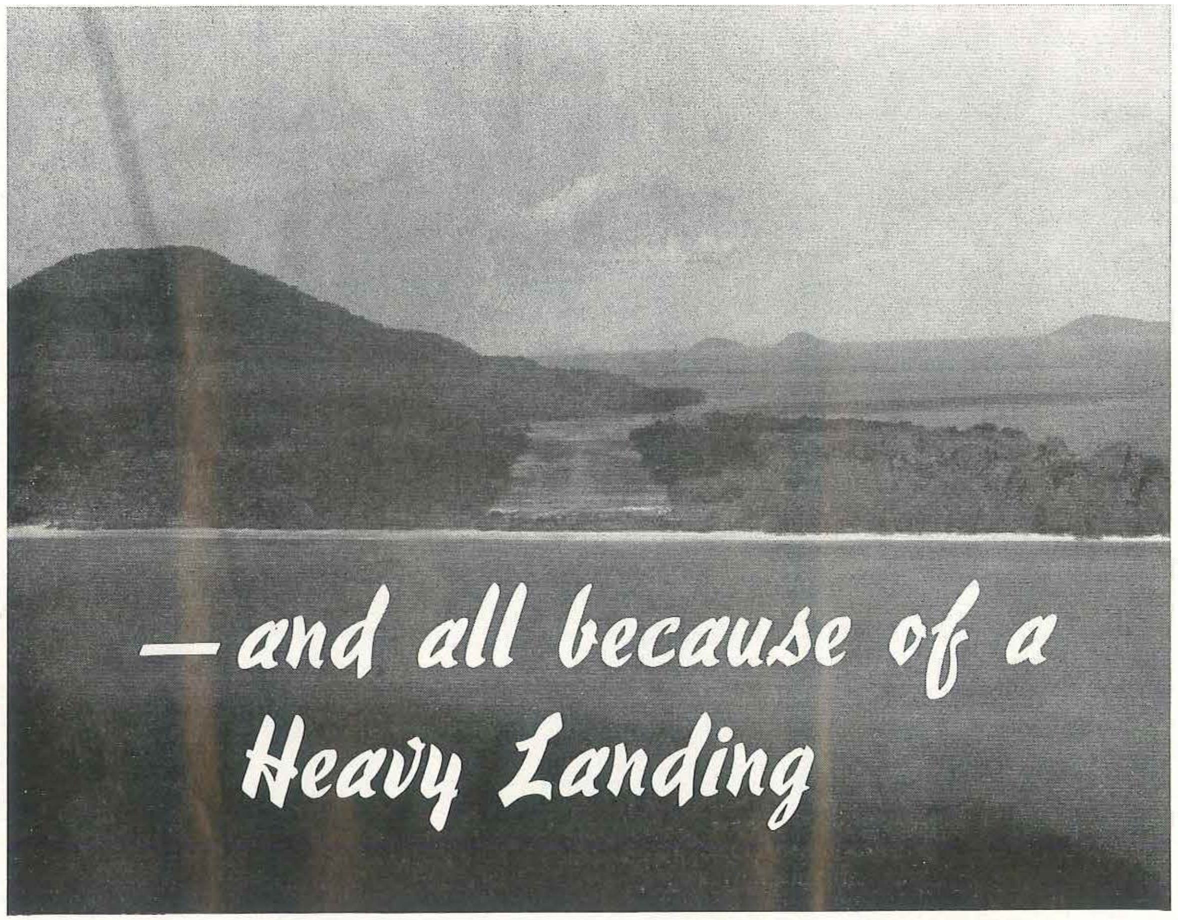
We are grateful to our contributor for exposing his misadventures in the interests of air safety. The point he makes concerning the effectiveness of pre-take-off checks is a very valid one. Most of us have probably been guilty at one time or another of going through our checks in a purely mechanical way without *thinking* what we are doing. For example, aren't there times when we carry out an engine run-up and religiously check the magneto switches, but completely forget to look at the oil pressure gauge? In most cases, we get away with this sort of thing because of the inherent reliability of the aircraft we are flying, or perhaps because the aircraft's controls have been left undisturbed since its last flight. In this case, the weaknesses in the pilot's pre-take-off checks were shown up after his normal shut-down routine was disturbed at the conclusion of the previous flight.

In case some readers jump to the conclusion that mistakes like this are made only by non-professional pilots, it is worth recalling that a commercial pilot, flying a Piper Aztec in New Guinea, was involved in a very similar type of incident not long ago.

After starting the engines for a charter flight, this pilot taxied to the runway holding point and carried out a full pre-take-off check, which included running up both engines and checking the fuel tank selectors, fuel pressures and tank contents. All seemed to be in order, so the pilot released the brakes, lined the aircraft up on the runway and opened the throttles for take-off. As the aircraft gathered speed, the port engine ran roughly and lost power. Immediately the pilot closed the throttles and abandoned the take-off.

To his credit, this pilot also wrote a detailed account of the circumstances leading to the incident, pointing out that it revealed a bad habit he had acquired without being aware of it. The pilot explained that as he usually flew the aircraft with fuel in both the inboard and outboard tanks, it had been his practice to use the outboard tanks first. This particular flight, however, was a comparatively short one and the outboard tanks had not been filled. The pilot nevertheless selected the outboard tanks from force of habit, and, despite his apparently careful pre-take-off drill, failed to detect that the fuel selectors were positioned to the empty tanks.

It is interesting to note that both these incidents are further illustrations of the truth that accidents rarely occur as the result of one isolated event — nearly always they are the culmination of a chain of events, any one of which in isolation would never amount to anything more than an incident. It is important to remember that the possibility of accidents is lessened only as these incidents are recognised and measures are taken to guard against their re-occurrence.



— and all because of a Heavy Landing

A PRIVATE pilot with two friends as passengers, all of whom were from Sydney, New South Wales, were making a holiday tour of the Queensland coast in a hired Cessna 182.

After staying overnight at Brampton Island, the party departed at 1015 hours the following morning for Dunk Island, 70 miles south of Cairns, with a planned refuelling stop at Townsville. The flight to Townsville was uneventful, and the aircraft was refuelled while the pilot obtained some information on the aerodrome at Dunk Island. The aircraft then took off from Townsville in fine weather at 1430 hours local time. Forty minutes later, after another uneventful leg flown below 5,000 feet, the aircraft arrived over Dunk Island.

The pilot cancelled his SAR watch by radio and noticed that the wind direction was nearly straight down the island's 14 strip, with a slight crosswind component from the inland side of the strip. Because of the strip's proximity to a ridge of hills on the island and the fact that he had encountered some turbulence in the circuit area while landing at Brampton Island the previous day, the pilot considered that similar turbulence could be expected during the approach. For this reason, in accordance with advice he had received from a commercial pilot before leaving Townsville, the pilot planned a shallow final approach to keep the aircraft below the level of the ridge. He flew the approach at the higher than normal speed of 75 knots, using 30 degrees of flap.

The aircraft encountered turbulence as expected, and, crossing the threshold, the pilot closed the throttle and began to flare for the touchdown. As he did so the aircraft struck the runway heavily in a slightly nose-down attitude and bounced to a height of about 20 feet. Although the pilot attempted to check the aircraft's descent, it again struck the ground heavily and bounced to a similar height and began drifting towards the right hand side of the strip. The pilot opened the throttle to full power to go around, but, on applying back pressure to the control column, he found that it felt abnormal and that there was a large backward movement of the control column before any control pressure or response was obtained.

As the airspeed increased the stall warning sounded briefly and the pilot relaxed the back pressure on the control column to allow the aircraft to gain speed. Immediately the aircraft nosed down abruptly, and the pilot had to re-apply back pressure to the controls to maintain a positive rate of climb. The aircraft also seemed to be unstable directionally, tending to swing to the left, and the pilot had to use a combination of aileron and rudder to hold the aircraft straight.

Flight path of aircraft showing approximate touch down points on Dunk Island strip, with subsequent track flown as the pilot attempted to go around.

As the aircraft approached the upwind end of the strip the pilot turned right away from the hills to carry out a circuit over the sea (see aerial photograph). Soon afterwards, while the pilot was still flying directly away from the island, the aircraft suddenly entered a diving turn to the left. The pilot recovered with some difficulty, but then experienced further trouble in maintaining control because of the aircraft's tendency to keep diving to the left. Concluding that one of the ailerons was damaged, and thinking that at any moment he might lose control altogether, the pilot transmitted a MAYDAY call, advising that the aircraft had a damaged aileron, was out of control and was going into the sea five miles north of Dunk Island.

Finding he could maintain a measure of control, the pilot then resolved to try and reach a small island approximately a mile straight ahead of the aircraft's position which during his circuit before landing he had noticed was inhabited. He continued to have difficulty controlling the aircraft as he approached the island, and decided that the safest course was to try and put the aircraft down in the water as close as possible to the shoreline. Approaching the island at low altitude, the pilot closed the throttle and ditched the aircraft in a tail-down attitude, without flap. The impact was not severe, but when the nose entered the water the aircraft somersaulted on to its back and came to rest on a rocky stretch of shoreline in water about four feet deep. The three occupants were uninjured and were able to extricate themselves without difficulty from the partly submerged, overturned aircraft.

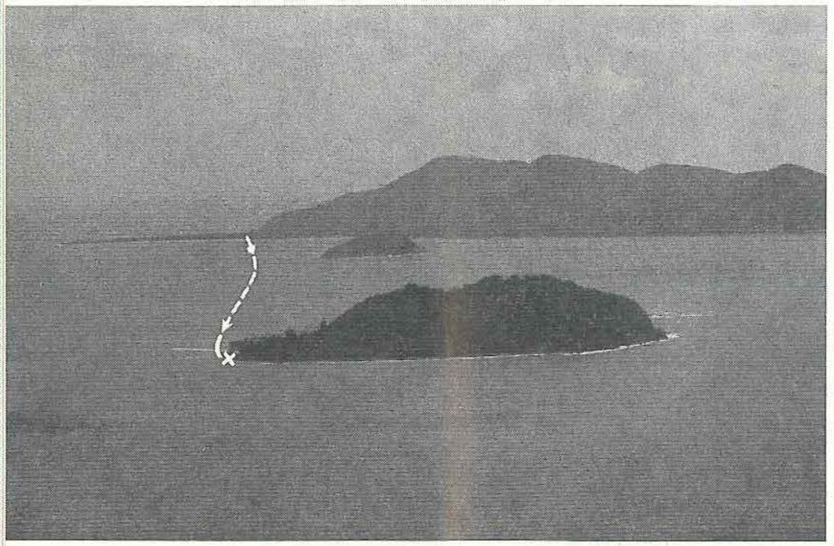
* * *

In the meantime, the aircraft's MAYDAY call had been heard at 1517 hours by a Departmental Fokker Friendship en route from Port Moresby to Cairns. The aircraft relayed the message to Cairns Air Traffic Control, and the Distress Phase was immediately declared. A PA-24 en route to Dunk Island was directed to search the sea to the north of Dunk Island and a Cessna 182, which was about to depart on a routine flight to Dunk Island, was requested to hold position to load inflatable dinghies that were being made ready by the Cairns airport fire service. The R.A.A.F. base at Townsville was contacted and requested to despatch a Neptune aircraft and an air-sea rescue launch to the Dunk Island area as soon as possible. Calls were also made to the Cairns Maritime Coastal Radio Station and to fishing authorities at both Cairns and Innisfail to ascertain whether any ships or fishing boats were in the area. The police at Tully, the nearest port to Dunk Island, were also contacted and requested to arrange for a boat to proceed to the area to join the search.

Both the R.A.A.F. crash launch and the boat from Tully were on their way to the area within 20 minutes of the MAYDAY call being received, and at about the same time the Cessna 182 departed from Cairns carrying the dinghies. The Departmental Fokker Friendship which received the MAYDAY call landed at Cairns to refuel and made ready to depart for the search area as soon as possible. Shortly afterwards the R.A.A.F. Neptune departed Townsville for the search area.

In the meantime, the PA-24 which had been searching the area reported no sightings. Because the telephone link to Dunk Island was unserviceable the aircraft was then asked to land at Dunk Island to alert the settlement to the emergency and to request another aircraft which was on the ground there to join the search. Shortly after 1600 hours a radio message was received from Bedara Island, four miles south of Dunk Island, that a fishing boat was available for the search and could reach the search area in an hour and a half. The vessel was requested to proceed to the search area immediately.

Soon afterwards a radio message was received by the aerial ambulance network from a resident at Thorpe Island, two miles south of Dunk Island, that the missing aircraft was upside down in the



Approximate track flown from strip on Dunk Island (in background) to point of ditching alongside Thorpe Island.

water close by the shore and that the three occupants appeared unhurt. The message stated that boats from both Bedara and Thorpe Islands were on their way to the scene. All aircraft and vessels proceeding to the search area were then recalled, and at 1632 hours the Cessna 182, which had joined the search from Cairns, reported that it was over the crashed aircraft. It was requested to hold position until the rescue boats arrived in a few minutes. Half an hour later one of the rescue vessels reported it had the three men from the crashed aircraft on board. The men were not hurt and were being taken to Dunk Island.

* * *

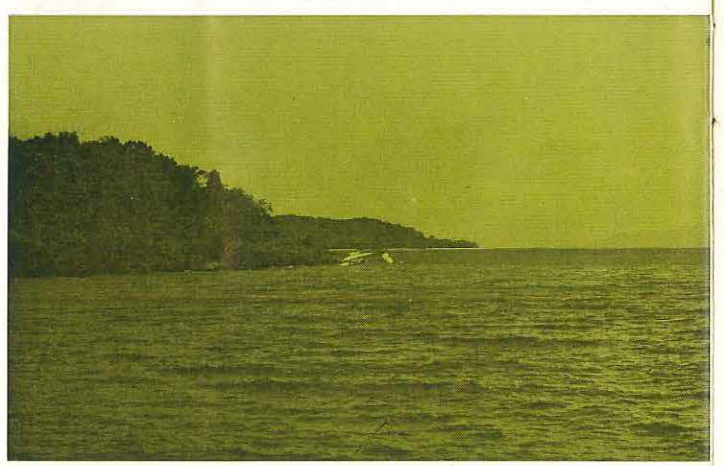
When questioned later, the pilot explained that with the control difficulty he was experiencing he became confused in transmitting the MAYDAY call and incorrectly reported he was five miles north of Dunk Island when he intended to convey that the aircraft was south of Dunk Island. The aircraft was actually about one mile south of Dunk Island at the time of the call. The pilot said he had been flying north-west and north-east all that day and, as this direction was prominent in his mind, he had said "north" during the MAYDAY call almost spontaneously.

Despite the fact that the pilot in his MAYDAY transmission indicated the aircraft had sustained damage to one of its ailerons, and later, during the investigation, was insistent that some malfunction of the aircraft's flying control system was responsible for the difficulty in controlling the aircraft, inspection of the aileron control system at the site of the accident did not reveal any evidence of pre-impact damage or malfunction. The aileron control cables on the damaged aircraft were slack, allowing the control wheel to move freely through about 75 degrees, but this was found to have occurred during the ditching, when the aircraft overturned in shallow water, causing some deformation of the wings.

Although the nose wheel strut had broken off completely during the ditching, the degree of damage and buckling sustained by the firewall bulkhead and the underside of the fuselage in the vicinity of the nose leg attachment was inconsistent wtih the pilot's and passengers' statements that the ditching impact was not severe. It was also found that the impact forces which had caused the damage contained a large vertical component in addition to the rearward acting forces to be expected during a ditching. The damage was severe enough to have displaced an elevator control pulley, allowing the elevator control cable to become slack, producing about three and a half inches of free fore and aft movement in the control column. It was also discovered that the buckling of the lower fuselage near the firewall had restricted the movement of the nose wheel steering rod, which is attached to the port rudder pedal shaft. This, in effect, meant that although the port rudder pedal could be moved to the fully forward position, it could not be completely returned to the neutral position, and resulted in the rudder being offset some ten degrees to port.

In view of the pilot's description of the aircraft's handling characteristics immediately following the two heavy touchdowns at Dunk Island, together with the type of damage which the aircraft sustained in the firewall bulkhead area, it was clear that the control problem experienced by the pilot was the result of the slackness in the elevator controls, together with the continuous application of some ten degrees of port rudder. It was the combination of these two effects which led the pilot to believe the aileron controls had suffered damage.

The aircraft upside down in shallow water by Thorpe Island, after the tide had gone out. The ditching took place at high water.



Nothing came to light during the investigation to indicate that the aircraft's flight control systems were other than completely normal up to the time of the landing at Dunk Island, and it was evident that the initial damage which caused the control difficulties and led to the ditching was the direct result of the heavy touchdowns. It was not possible to determine the exact reason for the pilot's heavy landing, but it was evident that it had resulted from either a change in wind gradient in the vicinity of the strip, which probably caught the pilot off guard, or simply because the pilot, approaching at a higher than normal speed, misjudged his height and flew the aircraft into the ground.

Cause

The cause of the accident was that the pilot did not exercise sufficient care in levelling off the aircraft for a landing.

Comment

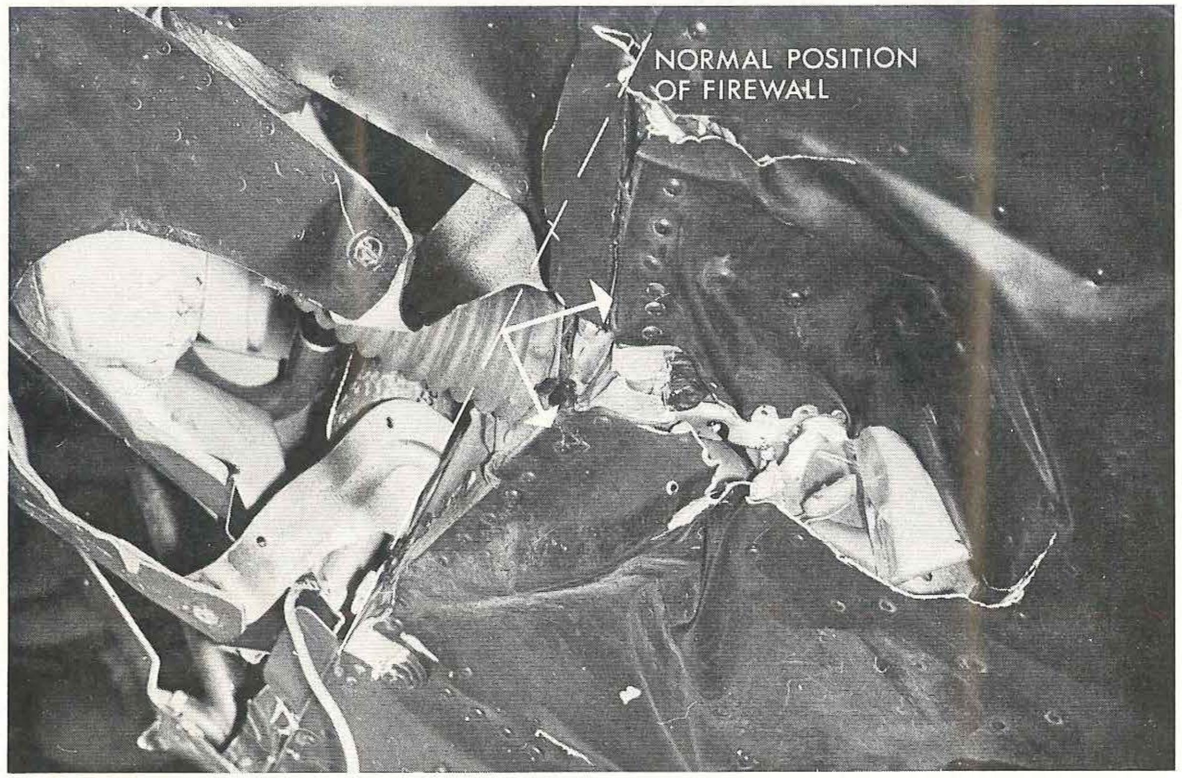
The Digest has on a number of occasions stressed how important it is for pilots to report any heavy landing they make so that the aircraft concerned can be inspected for possible hidden damage before it is flown again. The accident described in this article may be an extreme case, but it dramatically illustrates how far-reaching the effects of a heavy landing can be.

It is of interest that since this accident occurred there have been at least two more instances of the control systems of Cessna 182's being affected by heavy landings. In one of these cases also, the pilot found, after applying power to go around, that he was deprived of effective elevator control. Fortunately on this occasion however, the rudder controls had sustained no damage and the pilot was able to complete a successful circuit and landing with the aid of the tailplane trimmer.

In the other case the damage to the aircraft was not apparent at the time, but it was noticed later that there was some binding of the elevator controls. During a subsequent inspection the firewall bulkhead was found to be damaged.

In yet another instance, serious damage to a Piper Cherokee sustained during a heavy landing went undetected until a fuel stain was noticed beneath the starboard main fuel tank during a daily inspection. Further investigation then revealed buckling of the wing structure and a crack in the wing skin near the wing root.

Underside of forward fuselage and engine compartment, showing rearward distortion of firewall sustained during the heavy landing on Dunk Island. The resulting displacement of a control cable pulley caused slackness in the elevator controls.



things are a bit more CONGESTED than they used to be

Airlines of Australia Stinsons, Archerfield, Qld., 1936

Essendon Airport, Vic., 1969

So we must take precautions accordingly! At major aerodromes today, not only have a number of very large aeroplanes to fit into a limited parking space, but the very manner of their coming and going demands a great deal more care than was the case with piston-engined passenger aircraft of yesteryear. A thoughtless taxi-ing manoeuvre on the part of the master of one of the Stinson tri-motors depicted above might have done no more harm than to unceremoniously remove the hats of the group of gentlemen displaying so much interest in the marvels of modern air travel, but a similarly thoughtless slip by the captain of one of the DC9's shown on the opposite page could be the beginning of a very different story!

Turbo-jet airline aircraft have been operating on domestic routes in Australia for less than five years, but already there is an impressive list of accidents and incidents which have resulted from ill-directed jet effluxes while these heavyweights have been manoeuvring on airport aprons. Here are a few recent instances:—

- **A Viscount had just started its engines as a Boeing 727 was taxi-ing out for departure. Shortly after the Boeing moved past the Viscount's position on the apron, blast from the Boeing's jets picked up a metal passengers' sign and flung it into the Viscount's numbers 1 and 2 propellers, damaging both.**
- **As a DC9 turned and began to taxi out for departure its jet efflux swept across the front of the terminal building and the blast shattered a glass door. Two members of the public were cut by flying glass and a traffic officer sustained severe facial injuries.**
- **A Cessna 172 landed at a major airport and was directed to a parking area. The pilot shut down the engine and set the parking brakes while his passengers transferred to the airline terminal. Shortly afterwards a DC9 taxied past for departure, and while turning into a taxiway its jetwake was directed towards the Cessna. Just at this point the DC9's thrust was increased to assist the turn, and the unoccupied Cessna, caught in the increased blast, was lifted off the ground and tipped over on to its back.**
- **Three aircraft maintenance engineers, working on stands, were making some adjustments to the No. 3 engine of a Boeing 727 on the apron of a major airport when another 727, parked in the bay immediately ahead, commenced to taxi out. As the departing aircraft turned, its jet blast swept the length of the parked 727. Despite the fact that the stands on which the engineers were working were properly braked both stands were blown backwards quite violently.**
  One engineer fell to the ground, one was left hanging by his hands from the engine pod and the third rode one of the stands to a stop at the edge of a taxiway 100 feet away. Fortunately, the three engineers suffered no serious ill-effects, though two of them had to be sent home to recover from their experience.

Whatever faults have been responsible for these accidents and incidents, they cannot all be attributed to the crews of the jets—other persons concerned have also contributed their share in a number of instances. But, in this, as in most other matters involving air safety, we are not trying to single out individuals for blame—we are simply trying to eliminate the cause.

A consciousness of the dangers that lurk in the wake of a jet aircraft and constant vigilance to guard against their effects by all who are in **any way** involved with jet operations on aerodromes—including pilots of **other aircraft**—would go a long way towards eliminating the type of occurrences we have been discussing.

Inadequate Undercarriage Maintenance

UNDERCARRIAGE troubles are definitely on the increase. This fact is borne out by a recent analysis of accident and incident reports received by the Department over a period of 12 months, which shows a disturbing rise in the number of reports involving problems with undercarriages. Although the increase is to a certain extent understandable, considering the much greater number of aircraft fitted with retractable undercarriages now registered in Australia, the results of the analysis still give cause for concern that maintenance standards in some workshops leave a good deal to be desired.

Over the twelve month period under review no less than 173 accidents and incidents involving undercarriage system failures were reported. Since this figure includes regular public transport aircraft, as well as general aviation types, it is fair comment to say that neither section of the industry can afford to be complacent about the situation. Some idea of the extent of the overall problem can be gained from the way in which the total number of occurrences was made up, as shown in the following table:—

Undercarriage Collapse on Landing	12
Failure to Extend	13
Failure to Retract	18
Faulty Position Indications	73
Wheel Failures	6
Operational Causes	9
Failure of Fixed Undercarriage Structure	7
Miscellaneous	35

Many of the occurrences in the last category were without doubt the result of a combination of some of the other causes listed but, because of conflicting evidence or, in some cases, extensive secondary aircraft damage, they could not be definitely ascribed to any one category.

As well as the accidents and incidents listed above the Department is aware that there have been a considerable number of undercarriage problems that did not actually result in an operational accident or incident and which, for reasons best known to the individuals concerned, have not been officially reported. These additional occurrences, though they do not show in the Department's statistics, only add to the rather dismal picture portrayed by the official figures. Altogether, it is quite evident that there is very considerable room for improving the standard of undercarriage maintenance throughout the aviation industry as a whole.

It is well realised, however, that mere criticism, unless it is constructive, does little in itself to improve a given situation. With this thought in mind therefore, the Digest now proposes to discuss each of the types of failures revealed by the analysis, and offers advice which, if followed, should help to reduce the number of such accidents and incidents in the future.

UNDERCARRIAGE COLLAPSE ON LANDING

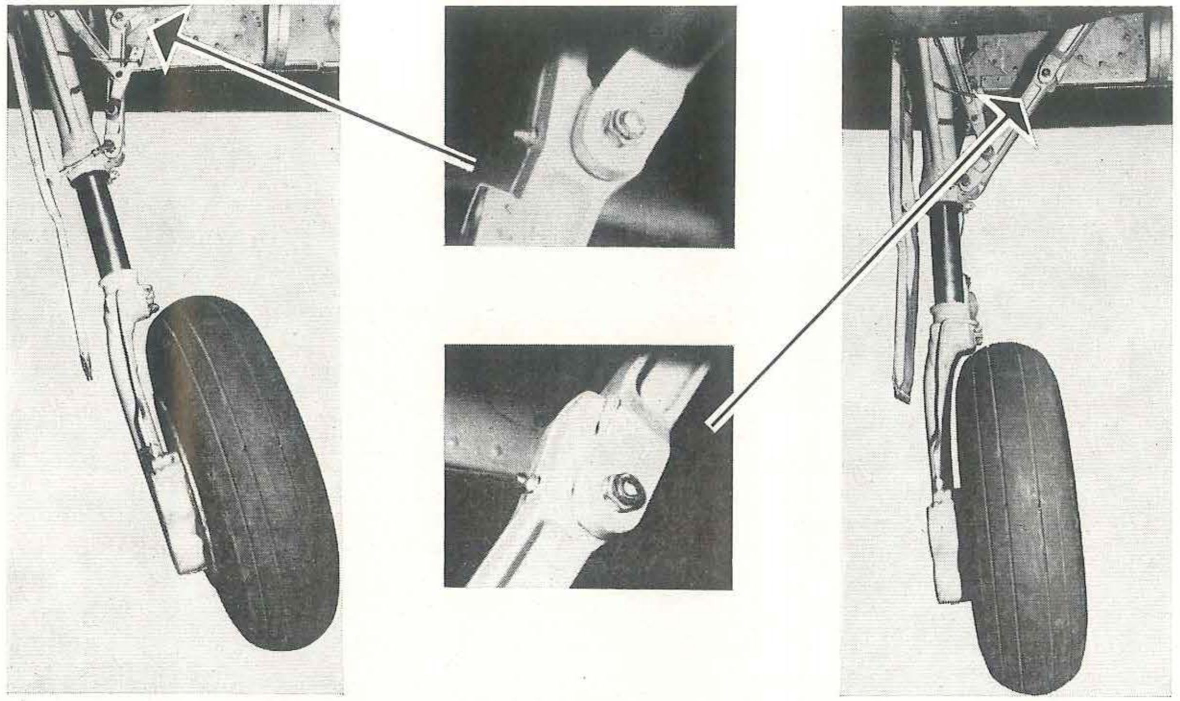
Accidents included in this category are those in which no abnormality in the actuation of the undercarriage was noticed by the pilot, the undercarriage appeared to be correctly extended according to the position indicators, and a normal touchdown was made before the undercarriage collapsed.

In every instance listed under this heading the pilot had no reason to doubt that the undercarriage was down and locked before attempting the landing and, when the final power reduction was made, no warning was given through the throttle switch system. In every case it was found that two faults existed in the undercarriage system —

(a) That the undercarriage was not fully extended to the locked position, and

(b) That the switches which activate the warning system were incorrectly set to the extent that the undercarriage position indicator showed a green light.

For the purpose of this discussion undercarriages fitted to most general aviation aircraft can be regarded as consisting of three main parts — the main shock absorbing strut, the bracing assembly and the retracting mechanism. The shock absorbing strut is designed to carry loads imposed on it by the weight of the aircraft during take-off, landing and taxiing. The loads imposed on the strut are mainly along its axis, but there are also drag loads caused by rolling friction, brake reaction, etc., and for this reason it is important that the strut is correctly aligned with the longitudinal axis of the aircraft. Side loads imposed on the undercarriage are normally absorbed by the somewhat lighter structure forming the bracing asssembly, which is usually composed of fixed length struts anchored to the aircraft structure. Where this type of bracing is used, it is customary for the main bracing strut to be provided with a pivot joint near its centre which allows the strut to fold. Adjacent to the pivot bolt on this strut are two mating surfaces which form a mechanical stop when the strut is pivoted slightly beyond its fully extended straight-line position. Thus, when the folded strut is being extended to the position it occupies when the undercarriage is lowered, the centre pivot of the strut passes through the theoretical straight line joining the two ends of the strut and continues over-centre for a specified distance (usually between 1-16th and $\frac{1}{8}$th of an inch) until the movement is stopped by the mating of the two surfaces (see photographs). In this position any compression load applied to the strut tends to force the mechanical stops further together and to push the over-centre pivot further in the downward direction. The



Typical light aircraft retractable undercarriage leg, showing over-centre type down-lock on the pivoted bracing strut. The operation of the mechanical stop can be seen in the insets. The stop allows the bracing strut to pivot beyond the specified over-centre distance, locking the undercarriage leg in the extended position.

undercarriage is thus said to be geometically locked and in this position is capable of carrying the loads for which it was designed. If however, the folding strut has not reached this over-centre position, it will naturally tend to return to the folded position as soon as compression loads are applied. When this occurs, a percentage of the load applied to the strut is transferred into the undercarriage retracting mechanism, the actual amount of the load transferred depending on the extent to which the folding strut is out of alignment. This situation is usually the beginning of the trouble which ultimately leads to the collapse of the undercarriage.

Like other mechanical systems, the retracting mechanism is designed on the assumption that it will be correctly maintained in service and, consequently, that the undercarriage will be geometrically locked in the down position whenever the aircraft is on the ground. While this remains so the only work that the retraction mechanism will be required to perform is the function for which it was designed, i.e., to raise and lower the undercarriage. Because of the need to save weight wherever possible, undercarriage mechanisms fitted to aircraft are designed no heavier than is necessary. While their strength is ample to perform the work for which they are designed, they will undoubtedly fail if they are overloaded by being forced to support the weight of the entire aircraft. This is so regardless of the size of the aircraft or of whether the undercarriage is operated mechanically, electrically or hydraulically. In all the undercarriage collapse accidents under review there was strong evidence that because of incorrect adjustment and, in some cases, worn components the undercarriage was not geometrically locked down and the retraction mechanism was actually holding the folding strut in position. Had these situations been detected in their earlier stages they could have been corrected before any damage was done. Because in each case, the fault was allowed to develop however, damage was caused to the retraction mechanism and its mountings by repeated overloading. This resulted in the undercarriage alignment becoming progressively worse and causing increased loading of the retraction mechanism until the collapse of the undercarriage was inevitable.

At this point is may well be asked why the warning system did not indicate an unsafe undercarriage condition. This will be discussed more fully under the heading Faulty Position Indications, and it will sufficient to say here that the principle causes were believed to be —

- Adjusting the warning switches in the undercarriage mechanism to correct discrepancies reported by the pilot, without first jacking the aircraft to test the operation of the undercarriage;
- Coarse setting of the warning switches to avoid "nuisance warnings" caused by vibration when operating on rough strips;
- Failure to replace worn pins and bushings as necessary in the undercarriage system. This type of wear cannot be detected unless the aircraft is checked with the undercarriage clear of the ground. With general aviation aircraft this should be done at least at every 100 hourly inspection.

FAILURE TO EXTEND

Several of the accidents under this heading were found to have causes which, though responsible for the failure of the undercarriage, did not originate in the undercarriage mechanism itself. Examples of this sort include electrical wiring and control switch damage and burst hydraulic system lines. For the purpose of this discussion however, only those faults will be considered which are directly attributable to the undercarriage mechanism itself and its associated components in the retraction mechanism.

Because each unit of an aircraft's retractable undercarriage (i.e., nose undercarriage, port and starboard main undercarriages) is made up of several components involving hinged struts, the complete undercarriage system may include up to 24 points requiring regular lubrication and inspection. Some of these pivot points are not easily accessible without first removing wheel and undercarriage fairings, and there is little doubt that this fact alone is often responsible for undercarriage retraction systems not being properly inspected and lubricated at 100 hourly inspections.

Many general aviation aircraft spend a large amount of time operating from unsealed aerodromes, and the considerable amount of mud and dirt thrown into the wheel wells in these conditions has an adverse effect on the pivot bearings, often leading to corrosion of bearing surfaces as well as increased rates of wear on pivot pins and bearing surfaces. In some cases, the resulting increased friction has prevented the aircraft undercarriage from reaching the fully extended position.

Some types of aircraft undercarriage mechanisms are provided with an "up-lock" for the purpose of supporting the undercarriage in the fully retracted position, thus relieving the retraction mechanism of the load of the undercarriage during flight. The undercarriage retraction mechanism includes a means of withdrawing this up-lock before the undercarriage is extended. Careful attention to the accurate rigging and periodic lubrication of these parts is most important if the undercarriage mechanism is to function correctly. If the up-lock withdrawal mechanism does not function correctly the undercarriage retraction linkage will obviously be damaged by overload. This can occur to the extent that, even though the up-lock may eventually be released by repeated operation of the undercarriage selector, the undercarriage will not extend to its correct position and will probably collapse when the aircraft lands.

In some other types of aircraft a rubber bungee cord is used to assist the mechanical retraction mechanism to ensure full extension and over-centring of the undercarriage down-lock. These bungee cords become weaker as their life extends and, although they may not show any visible signs of failure, they must be changed in accordance with maintenance manual requirements if the undercarriage mechanism is to continue to function effectively.

FAILURE TO RETRACT

Most of the faults discussed under the previous sub-heading may also adversely affect the operation of the undercarriage when it is retracting but, unless the aircraft has an indicator system which shows that the full retraction has occurred, such a condition may not be detected by the pilot.

During the retraction phase the undercarriage mechanism is working a little harder than it is during the extension cycle because it is raising the weight of the undercarriage. On the other hand, during extension, the weight is assisting the operation of the mechanism. Any weakness in the undercarriage system, such as a leak in the hydraulic retraction cylinder, or an electric motor with worn brushes or a dirty commutator, is thus more likely to show up when the undercarriage is being retracted rather than when it is being extended.

In addition to mechanical failures in the undercarriage mechanism which have occurred during the retraction cycle, there have been a few cases

in this category where manually positioned safety devices such as locking pins were not removed before the aircraft departed. Such devices are usually installed as a precaution against an inadvertent retraction of the undercarriage while the aircraft is undergoing maintenance on the ground, and their use is generally restricted to the larger types of aircraft. Incidents attributable to this cause are not usually dangerous, but they have a nuisance value in that they involve the aircraft returning after take-off. Also, because the pilot is unaware of the trouble before landing, he is compelled to report the situation as an undercarriage malfunction, which in turn causes an unnecessary alerting of emergency services and often results in adverse publicity for the operator concerned.

FAULTY POSITION INDICATIONS

This is by far the greatest cause of "false alarm" alertings of aerodrome emergency services, with all their attendant disruptions to normal traffic flows and needless inconvenience to so many people.

All aircraft fitted with retractable undercarriages are provided with an undercarriage position indicator system. Usually such a system makes use of red and green lamps to indicate whether the undercarriage is up or down, and, in the case of electrically operated undercarriage retraction systems, an amber lamp may also be included to indicate that the undercarriage is in transit when the undercarriage selector is operated. Some indicator systems which include an in-transit light omit the red lamp on the grounds that if the undercarriage is not down and locked and has passed through the in-transit stage it can be assumed to have retracted. When the undercarriage is selected down again, the in-transit light shows while the undercarriage is being extended, and is then replaced by the green light when the undercarriage is down and locked.

Position indicating systems of this type are controlled by a series of micro switches, actuated by moving components in the undercarriage mechanism itself. There are three principal types or arrangements of position indicating systems in general use today —

(a) Systems having three micro switches, one for each leg, connected in series with one green lamp, so that all three units must be down and locked before the green light shows;

(b) Systems having three micro switches and three green lamps, one for each leg and each circuit operating independently of the others.

(c) Systems having only one micro switch, which is situated centrally in the undercarriage operating mechanism and connected to one green lamp. With this system it is possible for the green light to show even though none of the undercarriage legs are actually in the fully down and locked position.

On electrically operated undercarriages the micro switches, in addition to operating the position indicators, are used as limit switches to cut off the power supply to the electric motor driving the actuating mechanism when the desired undercarriage position has been reached. If the setting of the switches is incorrect, the pilot will not only be given a false indication of the undercarriage position, but the motor may be automatically switched off before the undercarriage has been fully extended and locked. Alternatively, if the setting of the micro switch is incorrect to the extent that the switch is not actuated when the undercarriage has been fully extended, there is a strong probability of the undercarriage actuating mechanism being damaged by overloading. Again the pilot is at a disadvantage because of the false lamp indication, and may be unaware that the undercarriage is actually down and locked. In these circumstances, rather than risk a landing with an uncertain undercarriage position, he may elect to retract the undercarriage and make a wheels-up landing, causing needless damage to the aircraft.

Because of the resilience of the airframe structure to which the undercarriage members and the micro switches are attached it is useless to attempt to make any adjustments to these systems while the aircraft is subject to normal ground loads. For this reason it is most important that all settings and measurements be made with the aircraft supported on jacks. There are cases on record where pilots have reported erratic operation of the undercarriage position lights and the micro switch settings have been adjusted without first jacking the aircraft to verify that the adjustment was correct. In one particular instance, troubles and "adjustments" continued over several days of operation without being properly rectified and finally, the pilot was unable to obtain a green down light at all. Fortunately, the subsequent landing was uneventful because the undercarriage was actually safely down and locked, but there was an unnecessary disruption of traffic, alerting of emergency services and unfavourable publicity to the operator concerned. The final remedy for the trouble was quite simple, merely involving jacking the aircraft and making the correct adjustment. This could just as easily have been done five days earlier.

Experience accumulated over the 30 years that retractable undercarriages have been in use shows that maladjustments and faults which cause intermittent or erroneous undercarriage indications do not cure themselves. In the transitional period between an undercarriage system being fully serviceable and obviously unserviceable there may a time during which recycling the undercarriage may appear to produce a more positive indication of position. At this stage of development the fault in the system is obviously a marginal one, but it is nevertheless present, and, with proper maintenance can, and should, be rectified before it develops any further. In cases where a fault becomes apparent while an aircraft is operating in an area remote from any maintenance facilities it is frequently necessary to fly the aircraft in for an inspection. In these situations, it is often safer, after verifying by ground inspection that the undercarriage is in the fully extended and locked position, to make the flight with the undercarriage extended, rather than to retract it and risk a worse malfunction at the destination airport. Most undercarriage systems fitted to general aviation aircraft depend entirely on the over-centre type downlock to achieve a safe condition and, where a defect is suspected, it is usually quite easy to improvise an emergency means of ensuring that the folding struts do not move towards the retracted position during the ferry flight.

WHEEL FAILURES

Although the analysis for the 12-month period revealed only six incident reports involving the failure of aircraft landing wheels, many more instances have been reported by maintenance engineers and authorised workshops. The total figures indicate that the number of wheel failures in Australia, expressed as a percentage of the number of aircraft wheels in use, may be higher than in countries where most operations are conducted from sealed strips.

The majority of the wheel failures on general aviation aircraft have been found to originate from cracks on the inside of the flange and in the seating of the tyre bead. Some of these failures can be attributed to design weaknesses, but others are the result of incorrect tyre inflation and operations in "gibber" type country. A large number of light aircraft wheels are made on the split hub principle, in which the two halves of the hub are held together by bolts. Some of these hubs have sustained bolt failures because of design weaknesses in the specified bolt size, but others have undoubtedly been caused by incorrect torquing of the bolts. Uneven or insufficient tightening can lead to a fatigue failure of the bolt, while excessive tightening can lead to failure as a result of overloading.

Although the majority of the failures of this type are not easily detectable between 100 hourly inspections or tyre changes, at least some of them would be detectable if daily pre-flight inspections were carried out conscientiously. The high incidence of wheel failure obviously warrants greater attention to wheel inspections than has apparently been afforded these components in the past.

OPERATIONAL CAUSES

This category covers undercarriage failures directly attributable to the handling of the aircraft in service. It includes damage initiated by landings in strong crosswinds, heavy landings and similar occurrences, which have not been reported or have not been followed by adequate maintenance inspections. In some of the cases under this heading the final failure of the undercarriage has occurred while the aircraft was on a later flight to that on which the initial damage was caused, and close examination of the failed components has shown unmistakable evidence of the origin of the failure. Bolts and other structural members that have been overloaded nearly always exhibit tell-tale evidence when they are examined after failure. Although such evidence is not usually available early enough to prevent an accident, the risk can be reduced to a minimum by subjecting those components most likely to have been affected by abnormal flight conditions to specialised inspec-

tion methods. For this reason it is most important that pilots report to their maintenance organisations the nature and cause of any circumstances which could lead to a subsequent structural failure.

FIXED UNDERCARRIAGE FAILURES

Some of the points already discussed in this article are obviously applicable to both fixed and retractable undercarriages. There are, however, certain features on most fixed undercarriage aircraft which contribute to neglecting the proper maintenance of the undercarriage structure and its attachments.

In the first place, because most modern fixed undercarriages consist of a single strut per wheel, the undercarriage attachments are nearly always buried within the wing or the lower section of the fuselage, and it is essential to remove fairings to carry out a really adequate inspection. With aircraft of proven design, assuming it has not been subject to any abnormal take-off or landing loads, it is likely that the only trouble to be found in such areas is that caused by corrosion, and on this basis alone there would seem to be little justification for raising the aircraft on jacks at every 100 hourly inspection. However, because the major wear on an aircraft's undercarriage takes place in the direction in which the main shock absorber sections of the undercarriage and its attachments carry the weight of the aircraft, it is obvious that such wear will be effectively concealed unless the shock absorbers and associated structure are relieved of the aircraft's weight. For this reason it *IS* necessary that an aircraft be raised on jacks at every 100 hourly inspection. It is only in this position that the wear on oleo pneumatic shock struts, for example, can be effectively checked. Similarly, a security inspection of a spring steel type leg attachment requires that the load on the leg be removed. Using a single jack under each undercarriage strut in turn to lift the wheels clear of the ground while the wheel bearings and brakes are checked is simply not good enough for 100 hourly inspections.

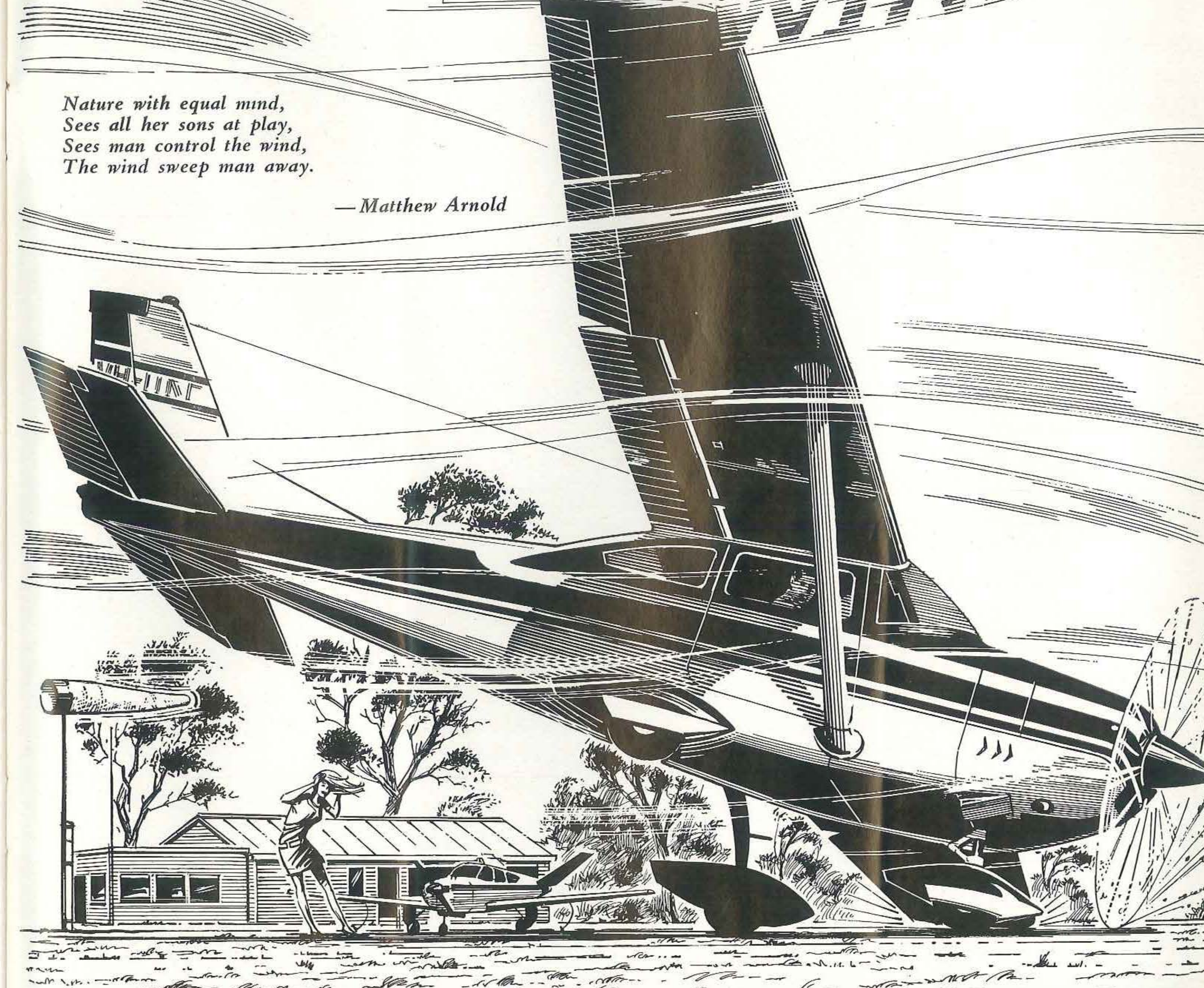
There are several types of light aircraft still in service which utilise rubber bungee cords as the shock absorbing medium in their main undercarriages. In the majority of these installations the rubber cord is formed into rings. If these rings are rotated at each 100 hourly inspection, so that the points of wear are changed, the rings will not only have a longer life but there will be a correspondingly greater opportunity to detect defects in the rubber before it fails. Serious damage to undercarriages of this type is often caused by the failure of the flexible steel check cable which should be installed with the rubber rings. The purpose of this check cable is twofold — firstly, to limit the amount of stretch which can be applied to the rubber rings by the undercarriage so as to avoid overloading them, and, secondly, to support the aircraft in the event of the rubber rings failing. In some accidents that have occurred in this category the check cable was either missing altogether or so badly frayed that it broke under the load when the shock absorber rings failed.

* * *

It is recognised that most light aircraft today are produced to sell on a highly competitive market and, like most other mechanical devices, they are prone to develop minor faults which become apparent only when they have accumulated some hours of service. This characteristic has been fully considered in this review of undercarriage failures, but it is clear that it has not been a contributing factor in these accidents and incidents. The answer to the problem appears to lie in greater acceptance by pilots of their responsibility to advise maintenance engineers of any discrepancies that show up during operation. Maintenance engineers, for their part, must ensure that the inspections and maintenance work they perform are as detailed and thorough as they can be and that they fulfil the spirit, the responsibility and the trust implied in the maintenance certifications which engineers are required to make before the aircraft is released for operation.

Undercarriage failures arising from neglect or lack of knowledge on the part of the pilots or maintenance engineers may not lead to fatal accidents, or may not even involve minor personal injuries, but they can, nevertheless, be costly and time consuming. It is hardly necessary to point out that the amount of money, time and effort expended in repairing damage sustained in accidents which could easily have been avoided, could be put to far better use in the aviation industry.

BEWARE THE WIND!



Nature with equal mind,
Sees all her sons at play,
Sees man control the wind,
The wind sweep man away.

— Matthew Arnold

Next time strong winds are forecast, some aircraft are going to be blown over — at least that's what we can expect if statistics are any guide. Within a 10-day period recently, no less than six aircraft were upset by wind while manoeuvring on the ground — all of them incurring damage of varying degrees.

If you HAVE to fly in high wind conditions, make it as easy for yourself as possible. As well as using ailerons and elevators to the best possible advantage while taxi-ing, employ ground handling assistance, especially when turning or taxi-ing crosswind. There are no prizes for doing it all by yourself — particularly if you finish up with your aircraft over on its back!