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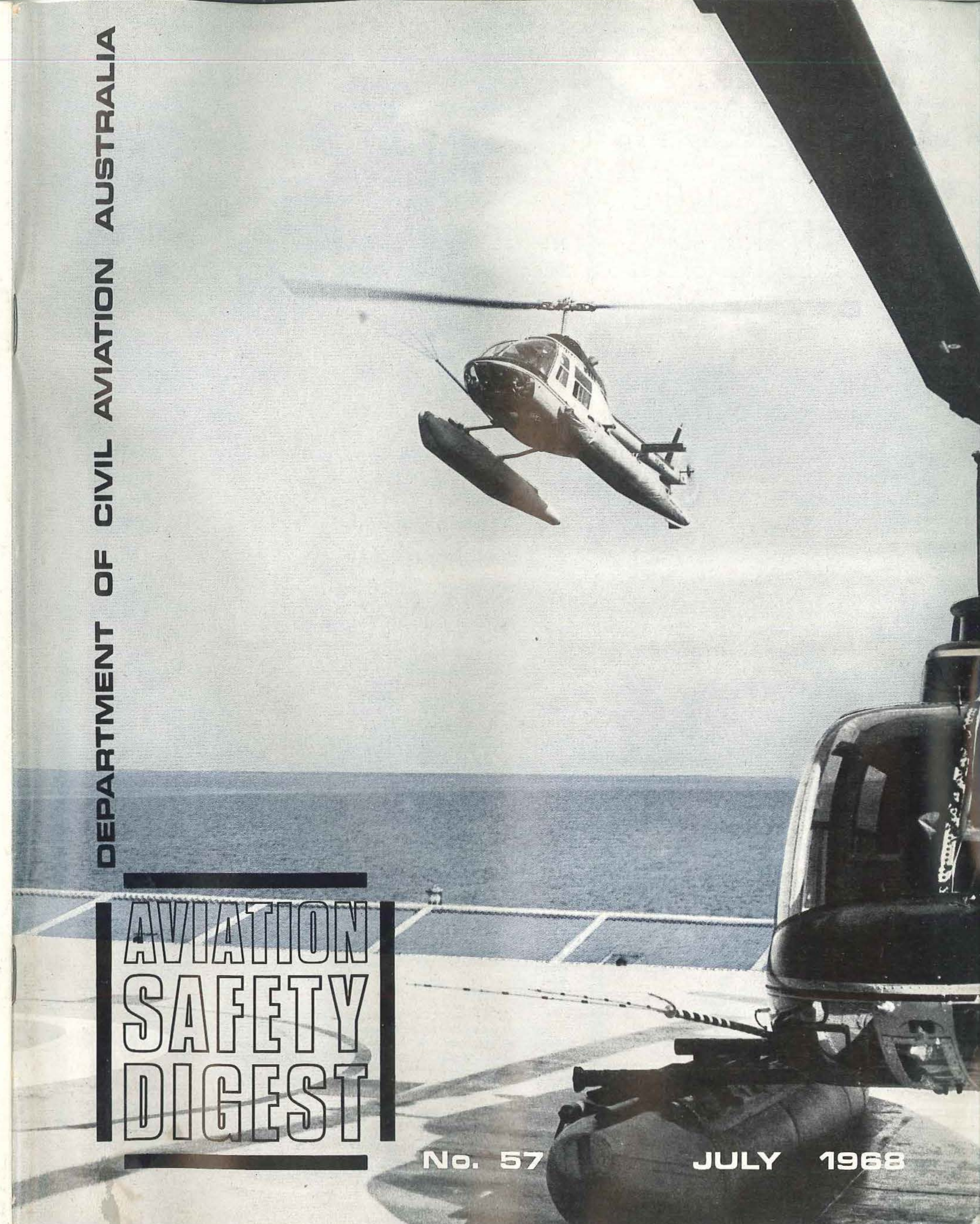

DEPARTMENT OF CIVIL AVIATION AUSTRALIA

AVIATION SAFETY DIGEST

No. 57 JULY 1968

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Contents

COVER: A Bell 206A approaching the helipad of the oil exploration vessel "Glomar Conception" in the Gulf of Papua. The trident-like "spear" mounted on the aircraft is a H/F aerial specially developed for use on helicopters, where the mounting of a normal H/F aerial is impracticable.

AUSTRALIA

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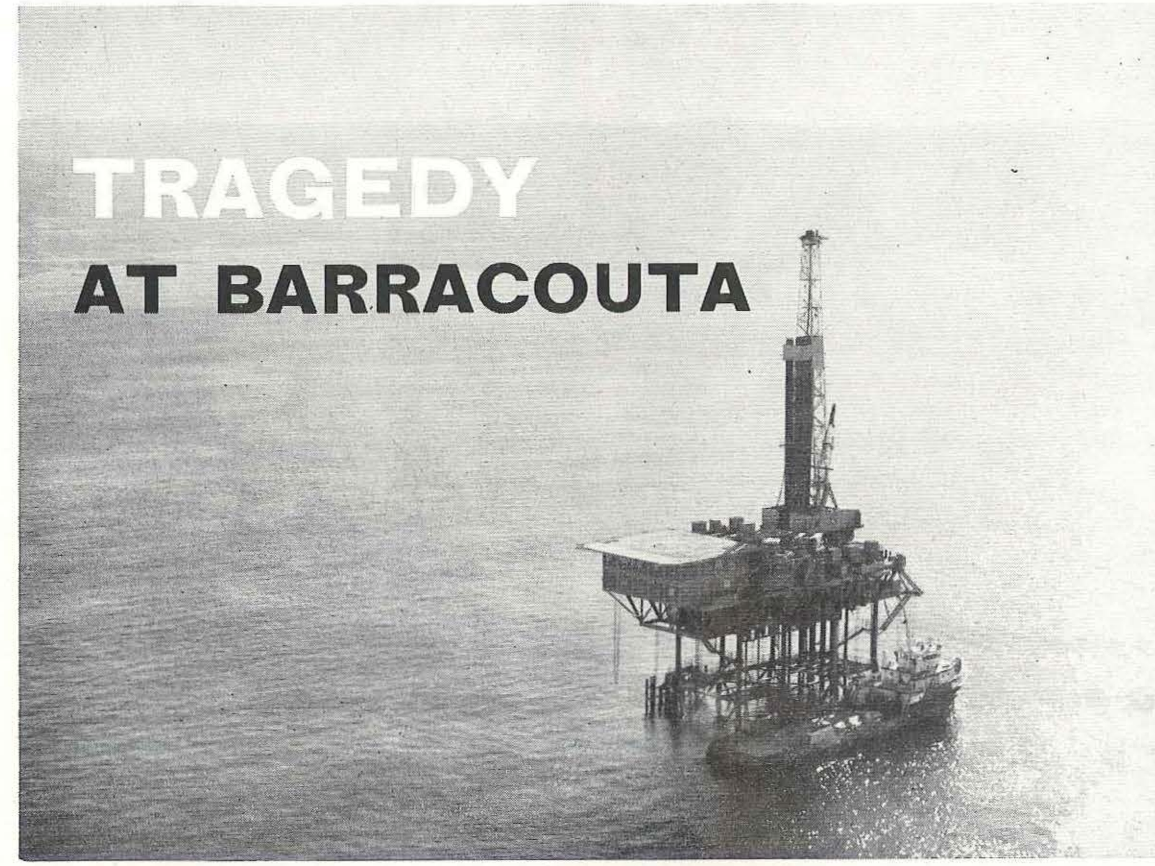
TRAGEDY AT BARRACOUTA



Barracouta Platform is a component of the new off-shore oil and natural gas recovery complex located in Bass Strait south of the Sale-Bairnsdale area of Victoria. This particular platform is 13 miles off-shore, standing in 150 feet of water and incorporates a helipad some 90 feet above sea level.

The Bass Strait petroleum development is of great significance and public interest to Australia and, with this in mind, the exploration companies had arranged for a party of 26 journalists, press and television cameramen and public relations personnel to visit Barracouta Platform. It was arranged that the party would proceed to the West Sale aerodrome in a charter aircraft on 22nd March, 1968, and from there to Barracouta Platform by helicopter. As the large capacity helicopter normally based at West Sale for the servicing of off-shore drilling platforms was expected to be out of service, a Bell 204B (the civil version of the military Iroquois) was transferred from Apollo Bay to West Sale on 21st March to be available for the task of ferrying the large group of visitors to and from Barracouta Platform. The party duly assembled at West Sale on 22nd March and the first group of eight departed in the Bell 204B helicopter for the platform shortly after 0800 hours. Two further trips were necessary to complete the movement of the party to the platform.

The third outward flight was completed just after midday and, by this time, the members of the first group to reach the platform had completed their mission and were ready to leave again for the mainland and for the luncheon which had been arranged. This party comprised mainly television cameramen who had been a little disappointed on the outward trip to find that their in-flight photography was handicapped by the closed doors of the cabin. The pilot therefore agreed to carry out a short local flight for the television cameramen, with the cabin doors open, before departing for the mainland. Four television cameramen and a journalist boarded the aircraft for this short flight.

The helipad on Barracouta Platform consists of a steel deck 60 foot square with a wire safety net extending for a further 4 feet horizontally around its perimeter. Access to the helipad is available via a stairway to a flush opening in the deck near the south-west corner. The helicopter took off at approximately 1215 hours for the short local flight around the platform and, about 5 minutes later, the purposes of the flight having been achieved, it began to approach the helipad again from the east. The approach was normal to a position of hover above the helipad with the heels of the undercarriage pontoons approximately 4 feet above the surface. From that position, and while settling slowly, the helicopter suddenly began to roll towards its starboard side. It touched down on the starboard pontoon, rolled and fell heavily on to the port pontoon and then slewed across the deck. The heavy rolling fall on to the port pontoon and the slewing of the fuselage snapped the undercarriage attachment joints and collapsed some of the pontoon cells. This permitted the fuselage and main rotor mast to lean at a marked angle, bringing the main rotor disc into contact with the helipad. As the rapidly decelerating main rotor blades made repeated and heavy contact with the deck, the outer portions of the blades disintegrated.

During this landing, a group of journalists and cameramen were standing at the south-west corner of the helipad, in the vicinity of the stairway opening. Some were on the deck itself while others were on various levels of the stairway. Several of the cameramen were photographing the approaching helicopter. In the short period between the initial loss of directional control and the final stopping of the main rotor blades, fatal injuries were caused to three of the party observing the landing and another four suffered serious injury. Fortunately, none of the six occupants of the helicopter suffered any serious injury.

* * *

The circumstances of the accident were immediately suggestive of a loss of directional control arising from failure of the tail rotor because of contact with some external object. One tail rotor blade had a significant dent in the leading edge, the other blade had become detached as a consequence of inertia loads and there had been a structural tear-out of the gearbox and remaining tail rotor assembly not inconsistent with the consequences of gross unbalance which would occur on separation of a blade. However, there was no matching evidence of contact with any part of the helipad or platform. Further examinations established significant patterns of soot staining and fretting along the fracture faces where the top of the tail fin, with its attached gearbox, had broken away from the remainder of the structure. The fracture faces were carefully preserved and subjected to a detailed metallurgical examination which confirmed that there had been fatigue cracking along a large proportion of the separation line. After many weeks of careful plotting the metallurgists were able to point to the probability that the cracking had commenced at a Dzus fastener cut-out provided to secure the tail rotor drive shaft cover and that the crack propagation rate had been so rapid that, in all probability, a very large proportion of it had occurred during the last two or three hours of operating time.

"BAIRNSDALE ADVERTISER" PHOTOS

A most potent source of fatigue-cracking loads in the tail fin area would be a condition of unbalance in the tail rotor assembly. The damage arising from the separation of one tail rotor blade prevented a balance check being made of the tail rotor assembly as a whole and so a careful dismantling had to be undertaken. At the outset it was noted that a substantial relative movement between the tail rotor yoke and the rotor shaft could be obtained and this was measured at .065 inches. At the conclusion of the dismantling process the two most significant facts discovered were that, although the manufacturer's instructions relating to centring of the trunnion would require that the trunnion shims (see Diagram of Tail Rotor Assembly, Item 7) be evenly distributed about the trunnion, this particular assembly contained a shim pack difference of .022 inches. It was also found that the nylon thrust washer was missing from the trunnion end at which the thinner shim pack was located. The missing component is illustrated as Item 5 in the diagram. In size, at 7/16ths of an inch diameter, it is no bigger than a shirt button and, in its installed position, it provides a spacing of approximately .060 inches between the end of the tail rotor trunnion and the trunnion bearing cap.

The helicopter had undergone a 100-hourly inspection on the 1st March, 1968, and the tail rotor assembly was changed at that time. The unit which was fitted to the helicopter on the 1st March had been assembled in the operator's workshops on the 28th February.

An immediate and careful search was carried out in the workshop, where this tail rotor had been assembled, and, amongst a small amount of dirt and other workshop waste found on the floor beneath a work bench support rail, the missing nylon thrust washer was discovered. The engineers involved in this assembly were closely questioned but it was apparent that they had no inkling that the thrust washer had been omitted from or had escaped from the assembly. This questioning did reveal, however, an explanation of the trunnion shim pack disparity. It is apparent that in the adjustment of blade grip spacing the engineers concerned incorrectly transferred trunnion shims instead of following the overhaul manual requirement to adjust blade grip shims. The trunnion was thus moved away from its central position in the yoke. It is likely that the thrust washer was in place when the procedure for eliminating trunnion end float was carried out and, indeed, it is difficult to envisage its absence at any time prior to the final adjustment for blade grip spacing. Nevertheless, the evidence of its omission and of the location in which it was recovered, clearly shows that it was lost from the assembly at some time prior to its release from the workshop.

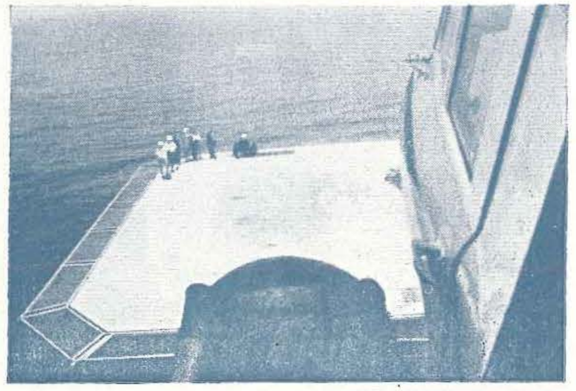
Stress calculations have shown that the forces to be expected from the degree of unbalance found in this incorrectly assembled tail rotor, would be sufficiently high to induce fatigue cracking of the tail fin and that this could progress to the point of ultimate failure within the flight time which this helicopter had experienced since the last tail rotor change. As already pointed out however, the metallurgical examination confined the cracking period to a much shorter span of flight time and pointed to the probability that all or most of it had occurred during the earlier flying on the day of the accident.

The eye-witness evidence, the pattern of

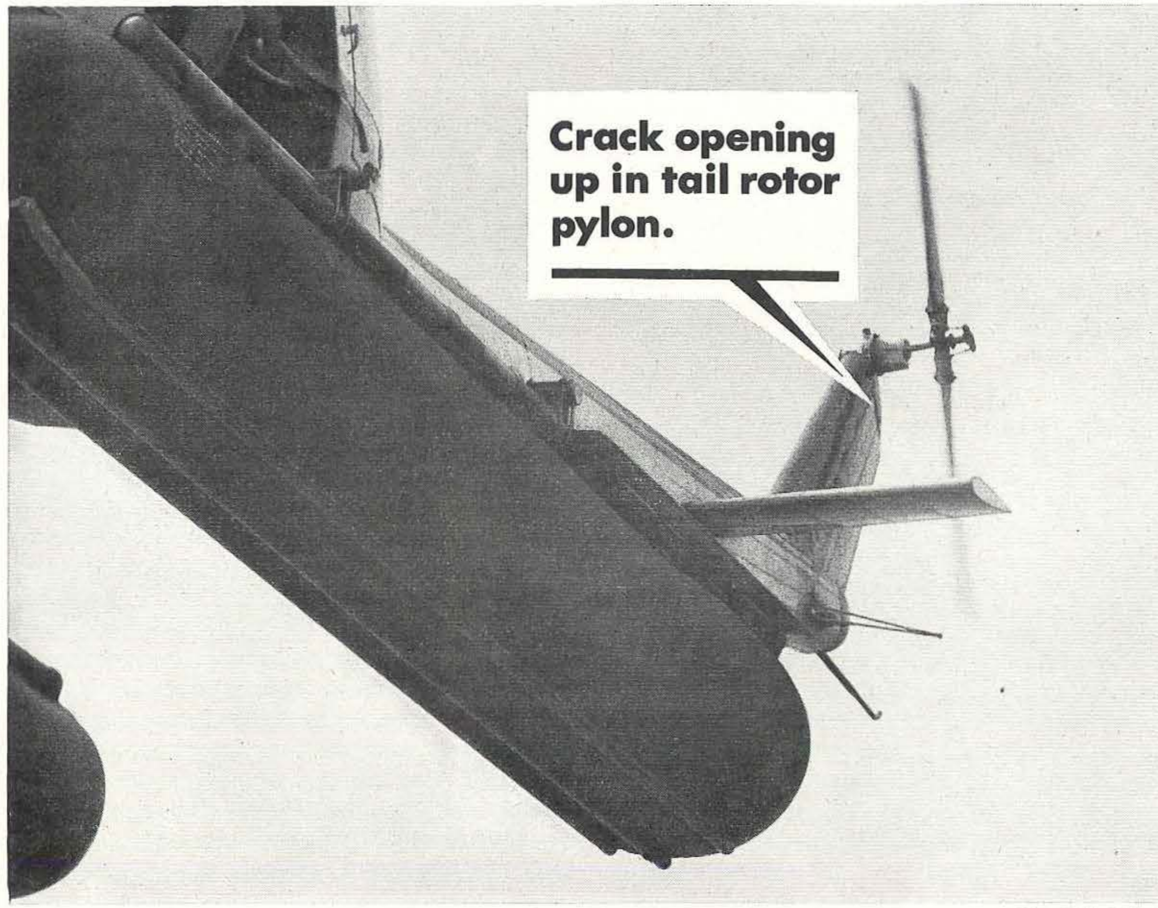
Left: The helicopter on the Barracouta helipad just before take-off.

Centre: The helicopter approaching the helipad for the landing.

Right: A frame from the cine-film taken from the helicopter during the approach, showing the group standing in the corner of the helipad.



"ATVO" TELEVISION PHOTO



"THE AGE" PHOTO

damage to the helicopter and on the helipad, as well as the results of the engineering and metallurgical examinations, have all contributed to a re-construction of the chain of events in this accident which can be accepted with a high degree of confidence. The final separation of the upper section of the tail fin and the attached gearbox and tail rotor assembly occurred when the helicopter was in the hover position above the helipad. In this way anti-torque thrust was lost and the pilot was thereby deprived of directional control when the helicopter was in a position where there was little that he could do to influence the further course of events. The dent on the one blade of the tail rotor was probably caused by contact between that blade and a section of the tail rotor drive shaft which was released after separation of the fin.

The investigation also included a careful examination of all film exposed by cameramen in the helicopter and on the helipad. Unfortunately, very little of value was derived from the examination of movie film since all the cameramen using this type of equipment, at the relevant time, were in the helicopter itself. The examination of film exposed by newspaper photographers observing the landing from the helipad revealed, however, that two of these photographers had, quite unwittingly, taken photographs which dramatically confirmed the re-constructicon of final events which had already been developed from other evidence.

The photographs are reproduced in this article and the first, reproduced on Page 4, was taken when the undersurfaces of the helicopter pontoons were approximately 10 feet above the helipad with the helicopter in the hover position. It shows, towards the top of the tail fin on the port side along the line of ultimate failure, a crack which has been opened up very substantially by the loads being imposed on the tail fin at the time. It is relevant that the tail rotor in this type of helicopter is a pusher type and thus, whilst it is operating, the port side of the tail

"BAIRNSDALE ADVERTISER" PHOTOS

Left: This photograph was taken when the helicopter had reached a hovering position approximately 10 feet above the helipad. The final stage in the failure of the tail fin is just beginning.

Above: This remarkable picture was the last to be taken of the helicopter before the accident. At this point the helicopter's pontoons were only four feet above the deck of the helipad. The enlargement at right shows clearly that the final failure of the tail fin had just occurred and the tail rotor shaft has pivoted into a vertical position, depriving the pilot of directional control.

fin is subject to tensile loads whilst the starboard side experiences compressive loads.

The second photograph on Page 5, was taken when the undersurfaces of the pontoons were approximately four feet above the helipad deck and it shows that the ultimate structural failure of the tail fin has just occurred. The upper forward section, including the tail rotor gearbox and the tail rotor itself, has rotated upwards about a hingeline running approximately fore and aft along the starboard side of the tail fin, so that the tail rotor is, in fact, rotating in a near horizontal plane. Having regard to the positions from which these two photographs were taken, it is apparent that the helicopter has yawed some 25 degrees to the right in the time interval between the two exposures but there is still no sign of the helicopter rolling from its normal hover attitude.

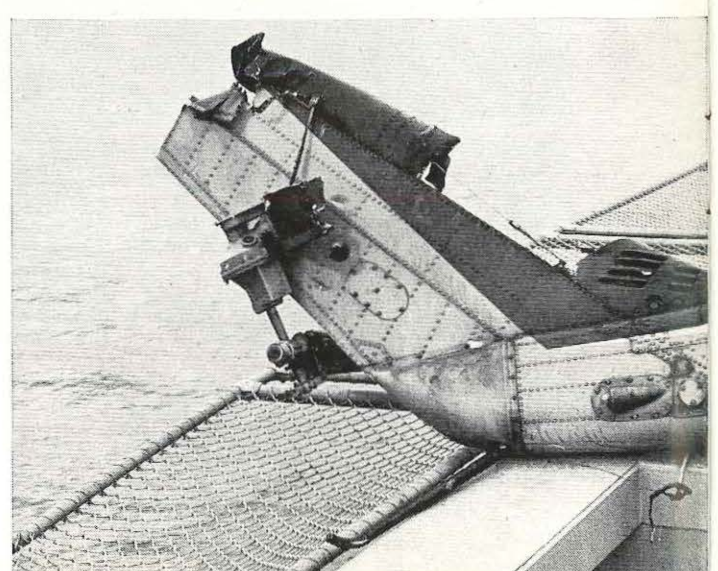
The investigation determined that the cause of the accident was the failure to detect the inadvertent omission or loss of the trunnion thrust washer during assembly of the tail rotor. The consequences of the accident, however, warranted consideration of the aspect of this landing being attempted while persons were on the helipad — it should not have been attempted in these circumstances and there was a radio channel available to the pilot to effect clearance of the helipad before carrying out the landing.

Over many months prior to this accident discussions had taken place between officers of the Department and representatives of the various helicopter operators to prescribe in detail the minimum dimensional standards for helipads and the conditions under which they could be used. The developed standards were consolidated as AIP/AGA-5-1 "Authorised Helipads" and were despatched to AIP holders during the latter part of February 1968. Paragraph 1.1 (d) of AIP/AGA-5-1 says that "adequate precautions shall be taken by a pilot to ensure that persons, objects and animals are clear of helipads during landing and take-off operations". Distribution of this section of the AIP was made to both the operator and the pilot of the helicopter involved in this accident.

It is known that distribution of this AIP material coincided with a period of unusual mail delays, nevertheless, it must be expected that the instructions would have been received by the operator, and by the pilot at his nominated postal address, during the first two weeks of March. It was apparent, however, that there was no reliable arrangement under which mail of this type,

Above: Aerial photograph of the damaged helicopter on the Barracouta helipad, taken soon after the accident. The access stairway can be seen near the helicopter's tail.

Below: The failed tail fin, showing the tail rotor hub and gear box torn away and retained only by the control cables.



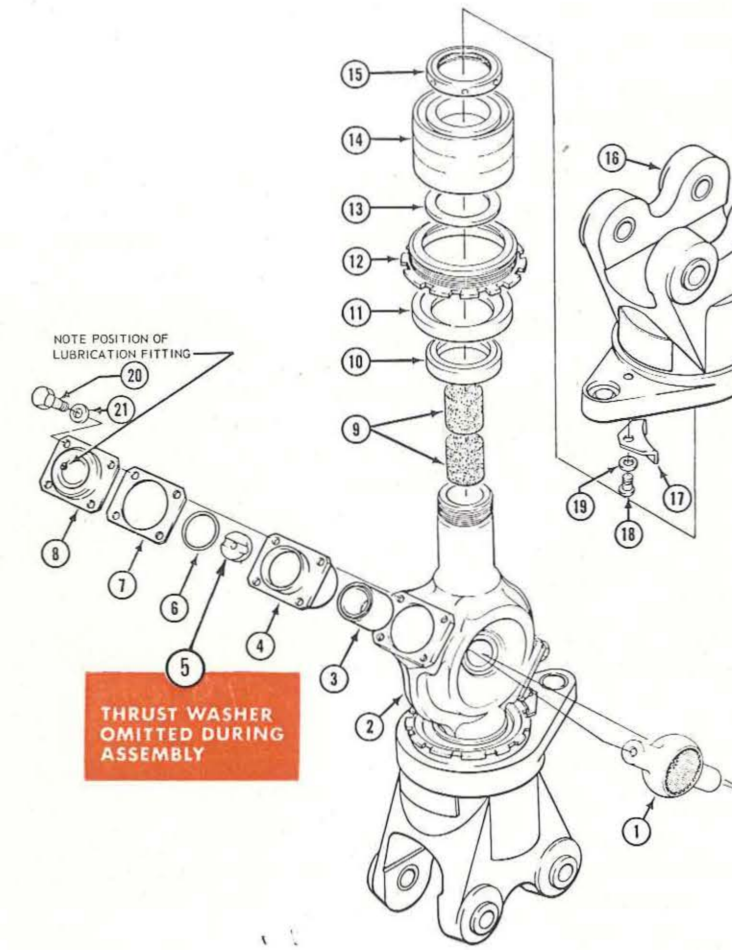
addressed to the pilot, would be expeditiously onforwarded to his actual place of employment in the field and, as a result, the pilot did not in fact receive AIP/AGA-5-1 until he returned to Sydney after the accident.

Prior to the implementation of AIP/AGA-5-1 the authority of the operator to use the Barracouta helipad was derived from the Company Operations Manual and the effective instructions relating to the presence of persons on the helipad were that "there shall be an obstruction-free area centred around the touchdown area giving sufficient space for the helicopter to safely manoeuvre". The manual also made it clear that the pilot-in-command has a responsibility to ensure that "adequate precautions are taken to keep all persons clear of helicopter rotors, particularly the tail rotor".

In this instance the pilot was carrying out a landing in a direction such that the persons on the helipad were in a far corner and would be continuously in his view. A landing in the centre of the helipad was intended and, in that circumstance, the nearest person would have been about 10 feet outside the perimeter of the main rotor disc, and below its normal plane of operation. Also the pilot's approach direction and intended landing orientation were such that he might conclude that danger from the tail rotor was eliminated. In these circumstances it was the pilot's belief that the presence of the persons on the helipad did not constitute undue danger to themselves or to the helicopter but it is possible that his judgment in this context may also have been influenced by his knowledge of the extent to which photography would play a part in the overall purposes of the public relations exercise in which he was participating.

Notwithstanding these factors, it is considered that persons should not have been permitted to remain on the helipad and the pilot's action, in carrying out a landing with them present, is considered to reflect acceptance of an unsatisfactory level of safety.

The accident is another example of the manner in which apparently unrelated events can set the stage for an accident and, all too often, a tragedy. From the investigation of this particular accident two points stand out clearly. They are the need for a meticulous adherence to specified procedures in workshops, and an appreciation of the fact that, other than in emergencies, there are NO circumstances which can justify a reduction of margins of safety.



1. Trunnion
2. Yoke
3. Bearing
4. Bearing Housing
5. Thrust Washer
6. O-Ring
7. Shim
8. Cap
9. Cork Seals
10. Radius Ring
11. Seal
12. Adapter Nut
13. Shim
14. Bearings
15. Nut
16. Grip
17. Lockplate
18. Screw
19. Washer
20. Bolt
21. Washer

Diagram of Tail Rotor Assembly, with rotor blades removed, showing component parts.

Side Slip Leads to Forced Landing

AFTER an overnight stay at Ayer's Rock, Northern Territory, a Beech Bonanza carrying the pilot and three passengers, departed for Alice Springs at 1100 hours local time. Approaching Alice Springs about an hour and a half later, the pilot reported 10 miles west of the airport and stated that he intended to fly over the town before landing. Flying a northerly heading just below 5,000 feet, the aircraft crossed the Macdonnell Ranges over Heavitree Gap. After crossing the range the pilot descended to 4,500 feet and continued north over the old Townsite aerodrome.

To allow his passengers a better view of the town, and enable them to take photographs, the pilot then depressed the aircraft's starboard wing, holding it down about 15 degrees. He maintained this attitude for about two minutes until the aircraft was some three miles north of the Townsite aerodrome, during which time the aircraft maintained a speed of 130 knots, but lost 300 feet in height. When he had passed the town itself, the pilot levelled out and resumed normal flight but very shortly afterwards, while the aircraft was still at 4,200 feet, the engine failed without warning.

The pilot immediately attempted to re-start the engine, exercising the throttle, turning on the fuel booster pump, changing the fuel tank selector from the starboard to the port tank, checking the magneto switches and exercising the mixture control, but all to no avail. When he saw that his efforts to restore power to the engine were not succeeding, the pilot turned off the booster pump again and gave his attention to the now inevitable forced landing.

The pilot had already made a turn to starboard, back towards the Townsite aerodrome, while carrying out his cockpit checks, but now he realised he was too far to the north to make a successful forced landing approach to this aerodrome. He therefore selected an open patch of ground on his port side, a mile and a half north-west of the town itself. The aircraft was now heading south-west and the pilot made a 180 degree turn to port, clearing a small hill by about 200 feet, to line up with the forced landing path he had selected. Having done this, the pilot lowered the undercarriage and flaps, and selected the propeller control to full fine, believing this would steepen the descent path. At this stage, the aircraft's approach speed was 80 knots and decreasing. Because the surface of ground was rough and uneven, the pilot intended to raise the undercarriage at the last moment and make a wheels-up landing. But as he was about to round out, the pilot had difficulty in controlling the aircraft. The port wing dropped and he attempted to pick it up with opposite rudder. This was unsuccessful, and a moment later the port wing itself and the nose-wheel struck the ground heavily. The nose strut collapsed, the propeller dug into the ground and the aircraft nosed over on to its back, slid for a short distance and came to rest almost a total loss. The four occupants, who were all strapped in, suffered only minor injuries.

* * *

A detailed examination of the aircraft disclosed no evidence of any malfunction, defect or damage having developed in the fuel or ignition systems before impact. It was nevertheless evident that the engine had failed from fuel starvation, despite the fact that both port and starboard fuel tanks were more than half full.

The investigation was therefore concentrated on determining the cause of the fuel starvation and the reason why the pilot was unable to re-start the engine in flight. Having in view the fact that the aircraft had been side-slipped for a time just before the engine failed, special attention was paid to the shape and layout of the fuel tanks.

The aircraft was fitted with long range tanks, installed in the leading edge of each wing, each having a capacity of 33.3 imperial gallons. These tanks are just over seven feet in length, are two feet wide and ten inches deep at the wing root ends, reducing to one foot wide and six inches deep at the outboard ends. Fuel is drawn from only one point in each tank, the outlets being located at the rear inboard corner of each tank. As the fuel tank selector had been positioned to the starboard tank at the time, it was considered that fuel starvation could have resulted from the starboard tank outlet becoming uncovered while the aircraft was being held in the prolonged side-slip to starboard.

To check the validity of this theory, a series of tests were conducted in another Bonanza having a similar engine and fuel system to the aircraft involved in the accident. The tests, which were made with approximately 18 gallons of fuel in the starboard tank, confirmed that a prolonged side-slip to starboard uncovered the fuel tank outlet and induced fuel starvation and engine failure in 25 to 59 seconds. Further tests to check the capability of the engine to re-start from this situation, established that it was not possible to re-start using the engine-driven fuel pump alone, and that, even with the booster pump switched on, the engine would not re-start if either the throttle or the mixture control were closed. However, with the throttle more than a quarter of an inch open the mixture control in the rich position, and the fuel selector positioned to either tank, it was found that the engine would re-start in two to three seconds.

The reason why the pilot was not able to re-start the engine after it failed could not be finally determined, but it was apparent that he had not carried out the engine re-starting procedure in the proper sequence. In the process, he apparently mismanaged the fuel system to the extent that fuel was not supplied to the lines at sufficient pressure to clear the airlock that had developed. The pilot admitted during a further interview, that he was unsure of the actual sequence of actions he had used to try and restore power to the engine.

The area which the pilot selected when he was finally committed to the forced landing, was the only available area that was relatively flat. There were however, numerous low mounds of sand and a few rocky outcrops on the surface, and it was suitable only for a wheels-up forced landing. In his efforts to position the aircraft to take advantage of the longest possible landing run, the pilot lowered the undercarriage and the flaps, as well as selecting full fine pitch, and approached to land into the north-north-east. The wind at the time was blowing from the south-east gusting to 15 knots and the temperature was +27 degrees centigrade. In these conditions of wind and density altitude, the pilot's approach speed of 80 knots or less was too slow, and he lost control of the aircraft at round-out height when the aircraft encountered a gust. In his attempt to pick up the port wing with rudder, the pilot evidently did not have time to raise the undercarriage as he intended, and did not check the aircraft's descent. As a result, the aircraft struck the ground heavily with the port wing and nose wheel, which collapsed under the impact, and the aircraft overturned.

Cause

The probable cause of this accident was that, when an engine power failure occurred, because of fuel exhaustion induced by prolonged side-slipping, the pilot did not follow the correct procedures for re-starting the engine.

Comment

As a result of this accident, the Department has introduced amendments to the Flight Manuals of all light aircraft in which the design of the fuel system is such that similar problems are likely to occur. The amendment to the Flight Manuals cautions pilots against prolonged un-co-ordinated flight such as slips or skids in these aircraft.

707 Breaks up in Air

(Condensed from translation of report of the Japanese Commission of Investigation published by Board of Trade, United Kingdom.)

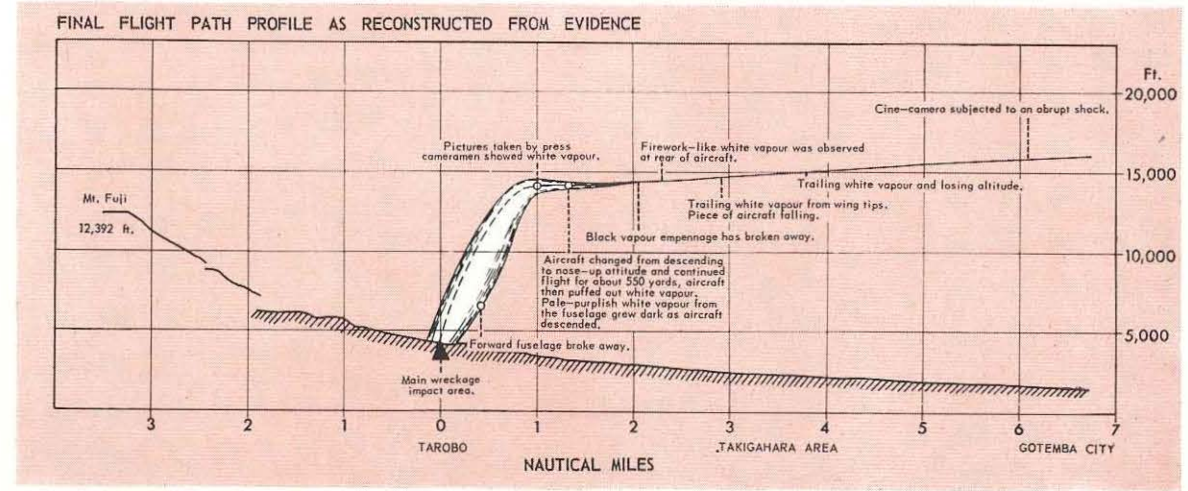
Soon after taking off from Tokyo International Airport, Japan, on a scheduled flight from Tokyo to Hong Kong, and while climbing towards Mt. Fuji in Visual Meteorological Conditions, a Boeing 707 broke up in flight. The main wreckage of the aircraft fell to the ground at the foot of Mt. Fuji and all 124 occupants were killed.

The aircraft had landed at Tokyo at 1243 hours and before re-boarding the aircraft the captain and the first officer were given a comprehensive weather briefing by the operator's duty operations assistant.

The aircraft's flight plan provided for a departure under Instrument Flight Rules, via the island of Oshima, 60 miles south of Tokyo, climbing to flight level 310. After the aircraft's engines had been started at 1342 hours however, the crew requested a VMC climb via Mt. Fuji. This was approved and the aircraft was cleared for take-off on Runway 33L and instructed to make a right turn. After departing Tokyo at 1358 hours, the aircraft flew south towards Yokohama, then still climbing, turned south-west and passed to the north-west of Odawara City. Nearing Gotemba City the aircraft turned towards Mt. Fuji on to a heading of about 298 degrees magnetic. Soon after passing over Gotemba City, ten miles east of Mt. Fuji, at an altitude of about 16,000 feet, the aircraft was seen to be trailing white vapour and losing altitude. Parts of the aircraft began to break away and, after maintaining a more or less normal attitude for a short time, the aircraft nosed down and descended steeply. Finally, over Tarobo, when the aircraft had fallen to about 6,500 feet, the forward section of the fuselage broke away, crashed to the ground and caught fire. The mid-aft section of the fuselage, with the major portion of the wing still attached, descended more slowly in a flat spin and struck the ground in a level attitude in a forest at the foot of Mt. Fuji. The sequence of the in-flight break-up as seen by eye witnesses, is shown in the diagram on page 11.

At the time of the accident, the meteorological situation was such that a depression had intensified during the previous night and moved rapidly north-east across Japan. After this, there was an anti-cyclone over the Asian continent and a depression over the sea to the east of Japan. A steep pressure gradient from west to east predominated over Japan at low levels. During the afternoon, westerly or north-westerly winds blew at the surface between Tokyo and Gotemba, the weather being fine with such good visibility that,

Right: The aircraft, trailing white vapour, begins its downward plunge near Mt. Fuji.



quite unlike the previous day, Mt. Fuji could be seen from Tokyo. At higher levels the winds were generally west north-westerly between Tokyo and the Mt. Fuji area.

The wreckage was scattered over an area 10 miles long and one mile wide and a reconstruction of the trajectories of the various pieces of wreckage, based on their distribution and the wind velocity at the time of the accident, established that the vertical stabilizer and the port horizontal stabilizer broke away somewhat earlier than the starboard outer wing, engine pylons and the forward fuselage, but beyond this it was not possible to determine the actual sequence of the in-flight break-up. The flight data recorder carried in the aircraft was destroyed by fire and no data was available. The recorder was carried as part of a civil aircraft airworthiness data recording programme and, at the time of the accident, there was no requirement for the carriage of a flight data recorder.

A detailed examination of the wreckage established that both fractures of the starboard wing had occurred in upward bending. All engine pylons were fractured at their wing attachments from a predominantly leftward load and the failure of the fuselage and the ventral fin and the vertical stabilizer were also to the left. The vertical stabilizer fractured at its attachments to the fuselage as a result of a leftward load and the starboard rear attachment fitting of the vertical stabilizer fractured at the upper bolt hole from tension load. Fatigue cracks were found on the fracture face of one of the bolt holes. Damage to the port horizontal stabilizer was extensive and scratches and paint adhesion were found which are presumed to have been caused by it being struck by the vertical stabilizer. Subsequently, the port horizontal stabilizer separated from the fuselage at its root. The starboard horizontal stabilizer, which was almost intact, broke away from the fuselage together with the centre section of the tail structure.

Apart from the fatigue cracks in the attachment fitting of the vertical stabilizer, no structural defects were found in the airframe structure, there was no indication of any flying control or other system malfunction and there was no evidence of any pre-crash engine defects. Nearly all the aircraft's instruments were destroyed, and no useful data could be obtained from them. The jack screw rod of the horizontal stabilizer trim actuator had fractured near the top end at the lower surface of the nut and the position of the trim jack corresponded to 1.4 units of nose down pitch trim on the cockpit scale.

An 8 mm cine camera belonging to a passenger was recovered from the crash site. It contained a colour film which showed scenes of Tokyo International Airport, the Tanzawa Mountains and Lake Yamanaka and, after skipping two frames, something like passenger seats, carpet, etc. appeared. The film then suddenly came to an end. Based on an analysis of this film and photogrammetry of each frame, the aircraft's altitude and flight path were assessed as shown on page 13. The airspeed was also assessed from this data.

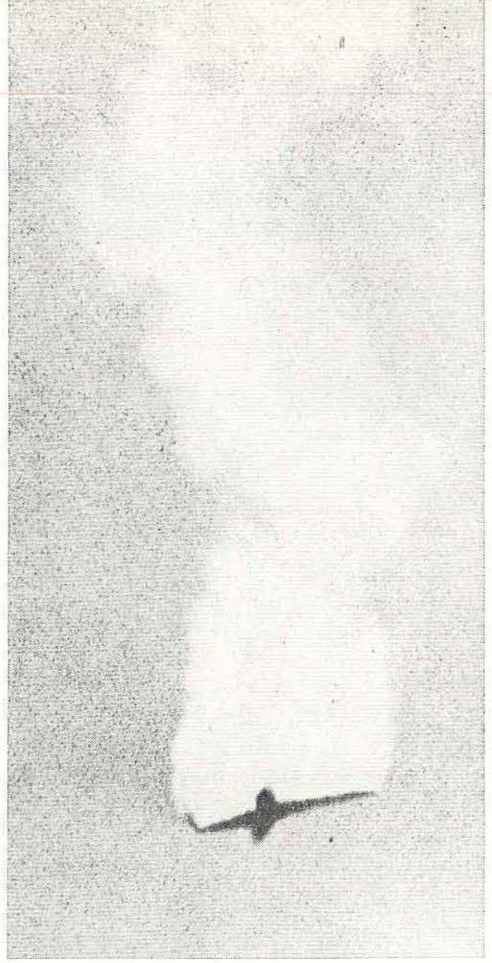
At the time of the accident, the indicated airspeed is estimated to have been between 300 and 380 knots and, judging from the estimated trim position of the horizontal stabilizer, it is highly probable that the airspeed was approximately 335 knots. The airspeed at the time of the accident, deduced from the analysis of the 8 millimeter colour movie film was 320-370 knots. Although no other data related to airspeed were available, 335 knots E.A.S. was taken as a standard reference for an analysis of airframe strength, since the estimates of airspeed ranges arrived at on these two bases are substantially similar.

Metallurgical tests conducted by the manufacturer of the aircraft on the failed attachment fitting of the vertical stabilizer showed that the fracture started from the upper outboard body frame attachment hole and progressed in a ductile tensile manner. The fatigue cracks found in the bolt hole were 1.9 and 1.4 millimeters deep. The final fracture was caused by a sudden load substantially greater than the load which caused the fatigue cracks in the fitting. The mechanical qualities in the material used were up to specifications. In a further test made by the manufacturer on another attachment fitting in which similar fatigue cracks were simulated, the fitting failed at a load corresponding to approximately 110% limit design fin gust load.

The aircraft operator's Flight Operations Instructions provide that their aircraft shall always fly on an IFR clearance; but VMC flight is permitted exceptionally, subject to restriction, to expedite the progress of aircraft in the stages of climb, descent and approach to land. In the case of take-off, a pilot-in-command may request VMC climb clearance from ATC, or accept VMC climb clearance from ATC, to expedite the progress of the aircraft, if, having sufficient separation from other aircraft, he considers a delayed departure clearance or a restricted climb clearance may be avoided.

The reason for the captain's request for a VMC climb via Mt. Fuji could not be established, but in view of the fact that there was other IFR traffic operating on the departure route, his request may have been made to expedite the aircraft's departure from the Tokyo area. It is also possible that the captain's request may have been associated with a desire to allow his passengers a better view of Mt. Fuji on this day of clear visibility.

Meteorological conditions at the time of the accident, were recognised as being favourable to the formation of mountain wave systems (see "Flight Over Mountains", Page 22). Strong west



The fuselage and main portion of the wing, descending in a flat spin. The tail section is missing and portion of the starboard wing is just breaking away.

to north-west winds were blowing with wind velocities increasing with height. At the weather station at the summit of Mt. Fuji, the wind was from the north-west at 60 to 70 knots. Upper air observations made at two other weather stations also revealed the existence of a stable layer of air below 9,500-13,000 feet.

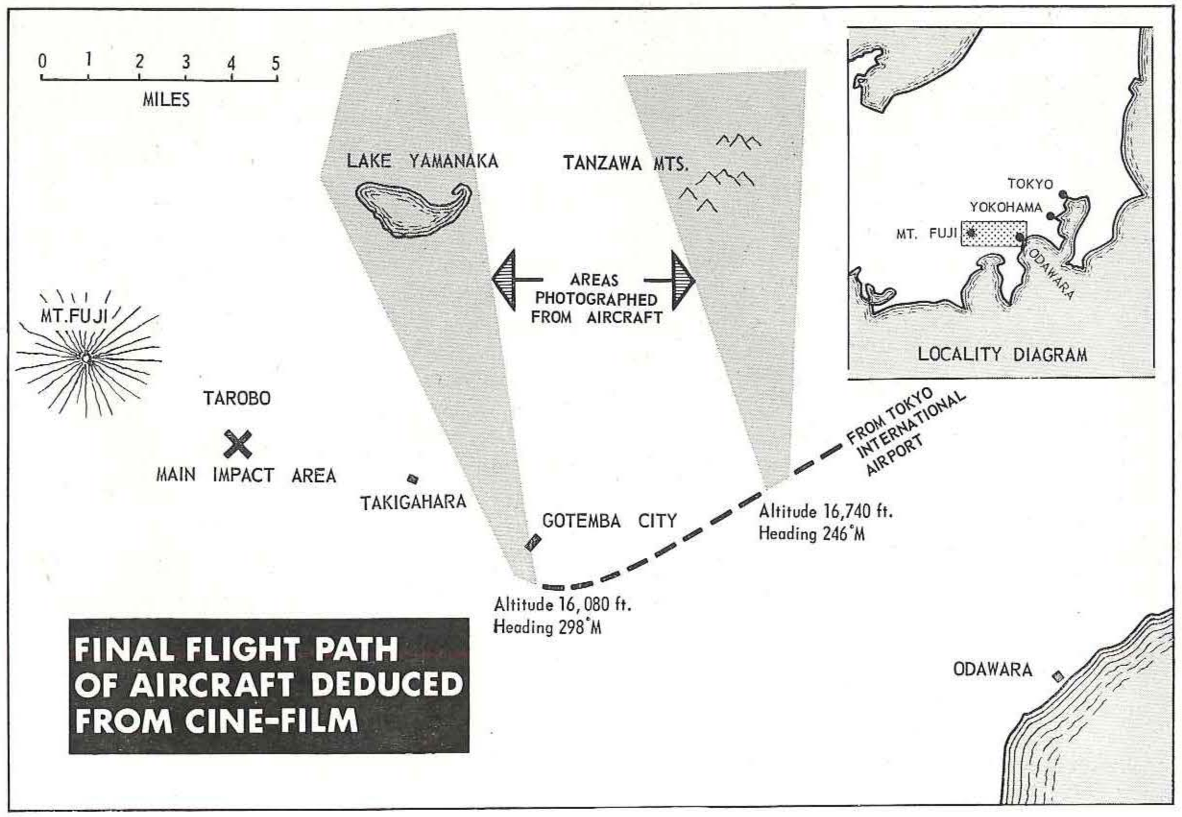
Weather satellite photographs taken only half an hour before the accident occurred, showed clouds characteristic of mountain waves in the lee of the Suzuka Mountain Range, 150 miles to the south-west of the accident site. Characteristic clouds did not exist in the lee of Mt. Fuji or other mountain ranges further to windward, but in all probability, this was only for the reason that the air was too dry to form cloud, and did not preclude the existence of mountain waves in these areas. Reports from 100 other aircraft which flew within 80 nautical miles of Mt. Fuji on the day of the accident, indicated that 79 of them had encountered turbulence in the area, mostly at altitudes below 10,000 feet. Four of the aircraft experienced severe turbulence in the eastern quadrant of a 27 mile radius of Mt. Fuji.

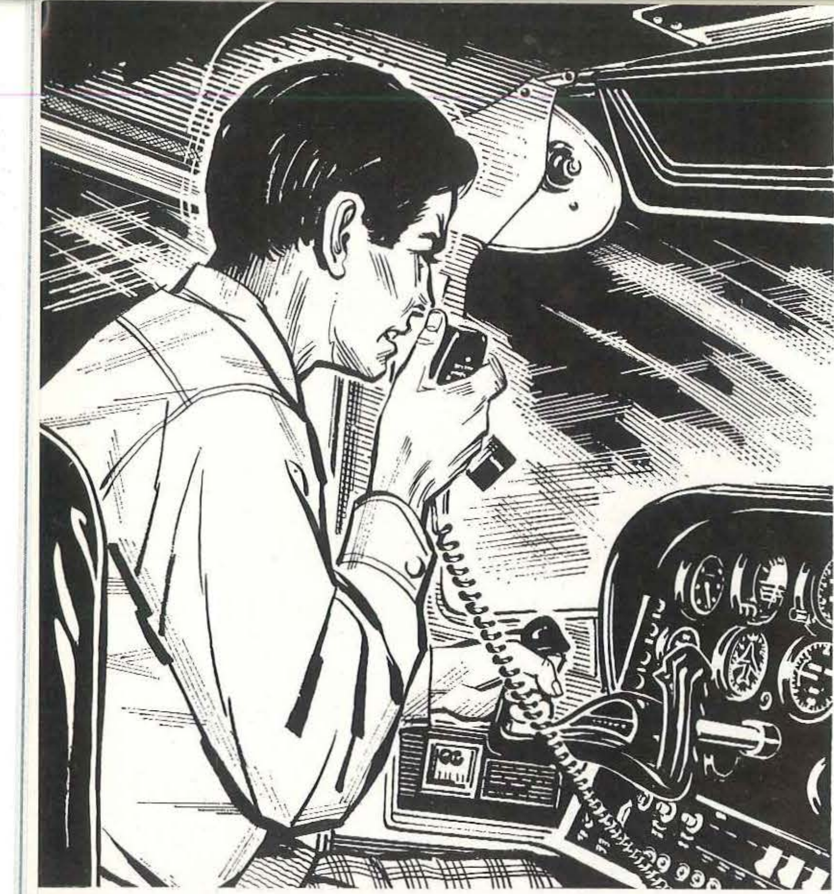
From the evidence of eye witnesses and the scattered distribution of the wreckage, it is clear that the aircraft broke up in the air, but it was not possible to establish the break-up sequence of the major portions of the entire aircraft. It was also impossible to determine clearly how much the fatigue cracks in the vertical stabilizer rear spar starboard fitting contributed to the break-up. The starboard outer wing was fractured in an upward bending direction but no evidence of excessive load applied to the port wing was found and it can be deduced that the upward bending load applied to the wing was an assymetric load with leftward component. As the other major parts were fractured by mostly leftward load, it is apparent that the aircraft broke up due to mostly leftward load. It is presumed that the aircraft broke up in a very short period of time due to an abnormally high gust load and resulting high inertia force in excess of the design limit.

If a strong mountain wave system existed in the lee of Mt. Fuji on the day of the accident, severe turbulence would have existed in any rotor portion and at the fringes of the system as in the case of mountain waves formed by mountain ranges. When strong winds blow against Mt. Fuji as they did on the day of the accident, it can be considered, irrespective of the existence of the mountain waves, that the downdraft current formed in the lee by the over mountain current, and the updraft current formed in the lee by the current detouring around the mountain complicate the current in the lee. It is not unreasonable to assume that on the day of the aircraft accident powerful mountain waves did exist in the lee of Mt. Fuji, and that the breakdown in the waves resulted in small scale turbulence the intensity of which might have become severe or extreme in a short period of time.

Probable Cause

The probable cause of the accident is that the aircraft suddenly encountered abnormally severe turbulence over Gotemba City which imposed a gust load considerably in excess of the design limit.





MISUNDERSTANDINGS - ON BOTH SIDES

A PRIVATE pilot was flying a Cessna 182 from Woolnorth Point, on the north coast of Tasmania, to Moorabbin, Victoria, proceeding via King Island, Cape Otway and Queenscliff. Before departing, the pilot obtained a route forecast by telephone. According to this, the pilot could expect three to five eighths of cloud at 2,000 feet, five eighths at 3,000 feet and a surface visibility of 20 miles. A cold front, situated between King Island and Melbourne, was expected to pass over Melbourne between 1100 and 1200 hours local time. The terminal forecast for Moorabbin indicated that until 1100 hours there would be six eighths of cloud at 3,500 feet, but with the passage of the front, this was expected to deteriorate to three eighths of stratus at 1,200 feet and five eighths of cumulus at 3,000 feet. The forecast was valid until 1200 hours.

After receiving the forecast, the pilot lodged a flight plan by telephone, with the Flight Service Unit at Wynyard, nominating a SARTIME of 1330 hours local time. The aircraft then departed for Moorabbin at 1030 hours.

The flight proceeded uneventfully until the aircraft was mid-way between King Island and Cape Otway. Here, the aircraft ran into rapidly deteriorating weather with low cloud and some lightning, and the pilot saw that he would have to turn back to King Island.

Some 45 minutes after landing at King Island, the pilot decided to try again and told the Flight Service Officer on duty he was departing for Moorabbin. After taking off he called the Flight Service Unit to say that the weather now appeared to be satisfactory and that he would continue. This time the aircraft completed the Strait crossing without difficulty, but in the vicinity of Cape Otway, encountered heavy rain and cloud down to 1,500 feet. There was no improvement in the weather as the aircraft flew further east and, by the time it reached the Mornington Peninsula, the cloud base had lowered to 1,200 feet.

At this stage the pilot switched his VHF receiver to the Moorabbin Aerodrome Information frequency, but was unable to hear any transmission. He continued towards Moorabbin and at 1343 hours when five miles south-east of the airport, called Moorabbin Tower, requesting "permission to land", stating that he was unable to hear any traffic information.

The tower replied "Negative", explaining that the aerodrome was closed because of poor visibility. In answer to a question by the pilot as to where he would be able to land, the controller replied that he was sorry but he didn't know and repeated that Moorabbin was closed. The pilot then asked about aerodromes to the south-east and the tower controller suggested Tyabb and Packenham, but added that these aerodromes also would be closed.

At this, the pilot flew off towards Packenham where he knew a friend of his had a private airstrip on his property. Approaching the property a short time later, the pilot flew low over the house to indicate he wished to land, but was waved away by a person on the ground whose signals indicated the strip was unserviceable. The pilot then assumed that as this strip was unservicable others in the vicinity were likely to be unserviceable also. In any case as he had no personal knowledge of these other strips, he decided it would be unwise to attempt a landing on them in the existing conditions. He therefore turned back towards Moorabbin and seeing that visibility was now good enough to be able to sight Moorabbin Airport from his position 10 or 12 miles away, decided he would have to land there whether it was closed or not.

When he was within five miles of the airport, just after 1400 hours, the pilot again called Moorabbin and announced his intention to land. The tower controller replied that the aerodrome was still closed and further exchanges between the pilot and the controller quickly became heated. Finally the tower controller became so incensed that he made the unfortunate statement that he was "not responsible for getting people out of trouble they get themselves into." Shortly afterwards, the aircraft made an uneventful landing and both pilot and controller submitted lengthy incident reports, each blaming the other for the situation that had arisen.

* * *

Investigation of the incident showed that both parties were in fact at fault, and that the unpleasant and even potentially hazardous situation could have been averted if either party had been a little more knowledgeable on procedures and perhaps a little wiser. All that was really required to meet the situation was the declaration of an emergency by either the tower controller or the pilot and all facilities would have been immediately placed at the pilot's disposal to ensure that he was able to make a safe landing.

It was found that the tower controller in this case was comparatively young and inexperienced. In addition, in his capacity as tower controller, he would not have had the advantage of knowing that this particular aircraft was arriving from a flight from as far away as Tasmania. His action in informing the pilot that the aerodrome was still closed, when the pilot said he intended to land, was correct, but he could have followed this with a question asking the pilot if he was faced with an emergency situation. There is little doubt that if he had done this, the heated verbal exchange on the tower frequency would not have developed. Even when the pilot made what were undoubtedly provocative remarks in reply to the controller's statement that the aerodrome was still closed, the controller could have retrieved the situation by disregarding them and advising the pilot that assistance was available in an emergency.

The pilot, for his part must also share some responsibility for the situation that developed. In the first place, though he had little alternative but to "press on" when he ran into deteriorating weather, at Cape Otway, his flight preparation beforehand left something to be desired. Before departing he had taken the trouble to obtain a route forecast, but having done this, he made no attempt to ensure that it remained current. The forecast he had been given earlier that day was valid only until 1200 hours, so that the delay

caused by having to return to King Island in effect meant that he later completed this leg of the flight without the advantage of a current forecast. In actual fact, a current forecast would have indicated that eight eighths of cloud at 800 feet could be expected at Moorabbin until 1500 hours, with rain, and visibility reduced to two miles. This up-to-date information could have been obtained for him by the Flight Service Unit at King Island, had the pilot requested it.

Secondly, there was no doubt that the pilot's lack of familiarity with operational procedures contributed in no small way to the incident. In his report on the incident, the pilot asked why he was not informed earlier during his flight to Moorabbin that the aerodrome was closed. It was evident that in choosing to conduct the flight on a "SARTIME" basis, which carries no mandatory in-flight reporting requirement, the pilot did not realise that he was automatically excluding himself from the obvious benefits of the Department's in-flight information service. Even so, it would have been prudent of the pilot, when he encountered the deteriorating weather at Cape Otway, to have called Melbourne and requested the present Moorabbin weather. This he apparently made no attempt to do. Even if he had passed a routine short position report to Melbourne at this stage, he would have been given the Moorabbin terminal information as the airport was by this time closed to VFR traffic.

Finally, having reached Moorabbin Airport after it was closed and found there was no suitable alternate, the pilot did not appreciate that he was operating in an emergency situation and needed assistance to conclude his flight safely. As in the case of the air traffic controller's omission. a declaration of emergency by the pilot at this stage would have triggered action to ensure that all possible facilities were extended to him.

As a result of this incident, the Department has taken steps to prevent similar misunderstandings occurring among Air Traffic Controllers. By giving this incident prominence in the Digest, it is also hoped that pilots, for their part, in future will be at pains to see that their own knowledge of operational procedures is sound. As well as taking a close look at their flight preparation methods in general, pilots would do well to see that they understand the full implications of the various flight notification categories as explained in the AIP and the Visual Flight Guide. Pilots should also remember that it is not only engine troubles and other in-flight malfunctions that constitute emergency situations. Navigational difficulties or unfavourable weather and aerodrome closures are equally eligible plights in which to be caught, and, if not promptly dealt with, can be just as costly in lives and aircraft.

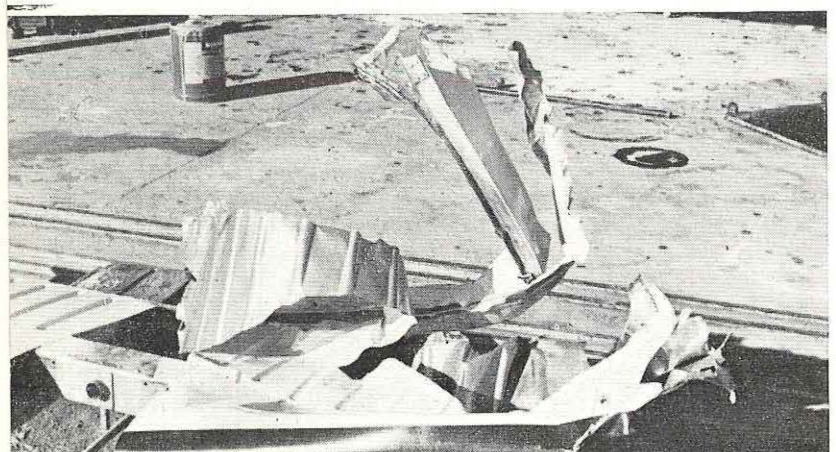
CLEAN IT FIRST

At Orange, N.S.W., a commercial pilot had been rostered for an urgent charter flight to Archerfield, Queensland, soon after first light.

The aircraft to be used, a Piper Cherokee, had been parked in the open overnight, and when the pilot went to carry out a daily inspection, he found that the aircraft's wings and windscreen were covered with a layer of ice. The pilot first tried unsuccessfully to scrape some of the ice off the windscreen, but then decided to taxi the aircraft to the apron to wash off all the ice with warm water. He climbed in, started the engine and let it warm, then began to taxi along the taxi-way, watching the edges of the taxiway through the storm window on the port side and the open door on the starboard side.

While he was manoeuvring his aircraft in this way, without any forward vision, it collided with the tail of another Cherokee parked near the apron. The pilot's aircraft sustained no damage, apart from minor scouring of its propeller blades, but the port tail plane of the other aircraft was literally slashed to pieces by the rotating propeller.

To his credit, the pilot admitted the incident was a case of "pure carelessness" and said that he had possibly allowed himself to be hurried by the urgency of the proposed charter.



The tailplane of the damaged aircraft after being removed for repair. The propeller of the other aircraft has literally hacked it to pieces.

FUEL EXHAUSTION!

THE pilot of a Cessna 172 was carrying out a navigational exercise from Whittlesea, Victoria, to Mt. Gambier, South Australia, via Moorabbin, Ballarat, Warracknabeal and Casterton. The pilot intended to refuel at Mt. Gambier and then return to Whittlesea.

Soon after leaving Moorabbin, the pilot became concerned about some errors which he found in his flight plan and landed at Ballarat. Here he spent 20 minutes on the ground correcting his plan before resuming his flight.

All went well until the aircraft was between Warracknabeal and Casterton, but at this stage the pilot saw there was low cloud and rain ahead on his intended track. He therefore diverted around the weather to the west, adding considerably to the distance flown, and on reaching Casterton, noticed that both the aircraft's fuel gauges were indicating less than four gallons in each tank. Still apprehensive about the weather, the pilot therefore decided to hold at Casterton while he obtained a further weather report. He called Melbourne and requested the weather report then, while waiting, looked around for suitable landing area, in case a precautionary landing was necessary.

Before he had succeeded in locating an area however, the weather report was transmitted to him from Melbourne, and indicated that the present situation was not worsening. The pilot therefore decided to continue to Mt. Gambier, concluding that in any case, the fuel gauges "would probably be under-reading".

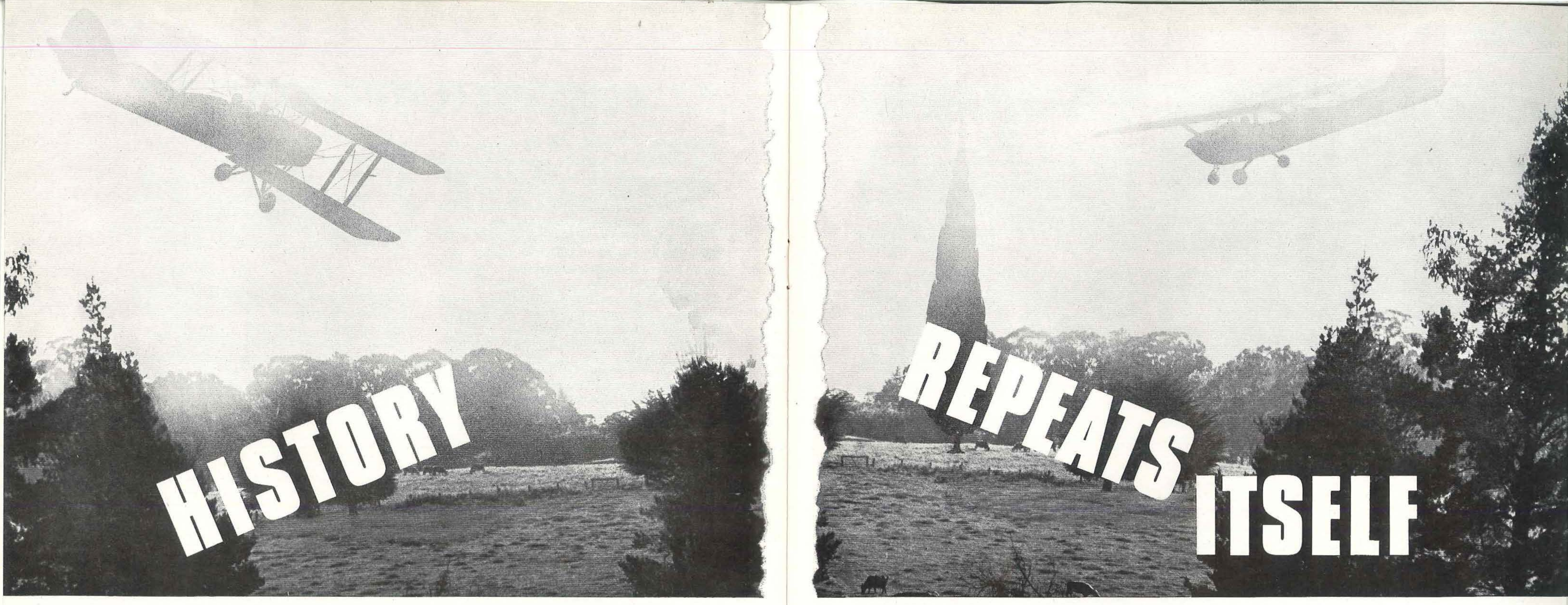
The Cessna subsequently arrived over Mt. Gambier more than 30 minutes after its ETA, with both fuel gauges showing zero. As the pilot began a descending turn to join the down wind leg of the circuit, the engine spluttered. It surged momentarily as the pilot straightened up again then stopped altogether. The pilot lowered full flap and turned the aircraft to line up for a downwind approach to the runway in use. The landing was successful but a DC-4 already lined up ready for take-off at the other end of the runway, had to be held while the Cessna was man-handled from the runway.

Examination of the fuel tanks showed that they were both empty. It was obviously very fortunate for the pilot that the aircraft had not run out of fuel before the aircraft was within gliding distance of the aerodrome. Had it done so a little earlier, a very difficult forced landing would have been necessary with much less happy results. Investigation of the incident revealed some discrepancies in apparent fuel consumption figures and it was evident that the pilot's planning of the flight lacked a good deal of forethought. By far the most significant fact to emerge however, was the discovery that *the actual capacity of the aircraft's fuel tanks was only 32 gallons five pints, instead of 35 gallons as stated in the aircraft flight manual.*

This discovery set in train a further, much wider investigation to establish whether this discrepancy was common to other Cessna 172 aircraft, and it soon became evident that a large number of aircraft were similarly affected. The most surprising aspect was the fact that the discrepancies had not come to light earlier, especially in view of the number of Cessna 172 aircraft operating in Australia. The matter was then referred to the manufacturers in the United States and after further investigation, the manufacturers issued a Service Letter (Refer Cessna Service Letter SE68-12) advising operators of the situation which, it was found, had developed as a result of an adverse accumulation of dimensional tolerances and changes made in their fuel tank manufacturing process. The Service Letter stated that the aircraft affected were Cessna models 172C to 172H inclusive, and that the fuel selectors on these aircraft should be re-placarded to show a usable fuel capacity of 36 U.S. gallons instead of the previous figure of 39 U.S. gallons, (i.e. a reduction in usable fuel from 32.5 to 30 Imperial gallons).

The Department has since taken steps to have the relevant Cessna 172 Flight Manuals amended to reflect these reductions in capacity. It is vitally important that all operators of the affected models take particular note of these changes and ensure that their aircraft have been re-placarded accordingly.

The manufacturers have since modified their manufacturing process to correct the discrepancies in capacity in fuel tanks fitted to the Cessna 172I and subsequent models. They have also informed the Department that other Cessna aircraft types have not been affected in a similar way.



And once again two people, who in the circumstances should have been killed, escape with their lives. (The trees must be soft in that part of the Tablelands!)

LATE in the afternoon of Sunday, 10th January, 1954 two private pilots were ferrying an aero club Tiger Moth from Goulburn, on the N.S.W. Southern Tablelands where it had been engaged in weekend flying training, back to its base at Bankstown Airport. Describing the circumstances of the flight later, Aviation Safety Digest No. 4 reported:—

"Before departing the pilot-in-command obtained a weather forecast for the route, which indicated that the cloud base would be approximately 1,500 feet above the general level of the terrain with thunderstorms in the area and he was informed that, at the time of his enquiry, the cloud base at Bankstown was 800 feet. After discussing the situation with the senior operations officer at Sydney the pilot decided to 'give it a go' and lodged the appropriate flight details.

The aircraft departed Goulburn at 1615 hours and levelled out at 500 feet following the main southern railway line to Sydney. This cruising level was only 200 feet below the cloud base, and some 25 minutes after departure some lower patches of cloud appeared on the track and the aircraft descended to pass under them. The pilot then observed even lower cloud moving in from the north and he decided to return to Goulburn. Just as he completed a turn to the left on to the reciprocal track the aircraft entered cloud and the pilot endeavoured to hold the aircraft on an even keel whilst descending slowly to regain visual reference. Before this could be obtained the port wing struck a tree and the aircraft swung violently to the right, struck another tree and crashed into a small clearing."

The site of the crash was within half a mile of the township of Wingello on the main southern railway line. Wingello is situated on undulating tableland country timbered with tall trees, some 70 miles south-west of Sydney and is 2,200 feet above sea level. Miraculously, although the aircraft was destroyed as the photographs on the next page show, the two occupants sustained only minor injuries. The Digest article concluded:—

"In view of the weather forecast provided to the pilot and the nature of the terrain to be traversed, there was quite a probability at the outset that the flight would not get through and, indeed, this was apparently appreciated by the pilot. However, it is considered that the pilot should not have continued the flight beyond the point at which he noticed lower cloud appearing whilst cruising just below the base at 500 feet. It would have been sensible to have abandoned the flight and returned to Goulburn at this point but he persisted in trying to get through until he could not even make a turn without entering cloud.

The cause of the accident was an error of judgment by the pilot in attempting to continue the flight in such conditions of weather that visual flight could not be maintained."

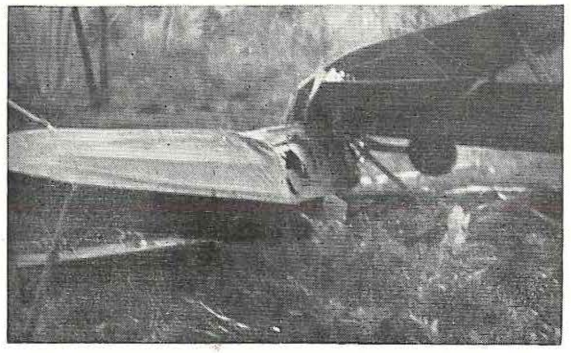
* * *

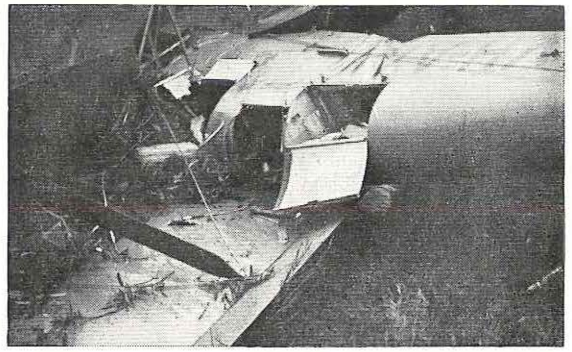
Almost 14 years later, the pilot of a Cessna 182 making a charter flight from Sydney to Tumut, N.S.W. with one passenger, was attempting, in similar weather, to "get through" this same area of tableland country, though in the opposite direction. Like the pilot of the Tiger years before, the Cessna's pilot was attempting to navigate in marginal, deteriorating visual conditions, by following the main southern railway line.

The aircraft had departed Sydney at 1200 hours and, until it reached the vicinity of Picton, the flight proceeded uneventfully at 2,000 feet. But from Picton onwards, as the aircraft continued over the gradually rising terrain of the tablelands, conditions gradually worsened. Nevertheless, the pilot flew on, keeping the railway line in sight by flying as low as necessary. At first, the cloud base above the terrain was about 1,000 feet, but as the flight continued, some of the hill tops were seen to be in cloud and by the time the aircraft had reached the Mittagong-Bowral area, the cloud base was less than 500 feet above the ground. Instead of turning back towards better conditions however, the pilot pressed on, descending further to keep the ground in sight, and followed the railway at reduced speed. A few miles further on the cloud base was reduced to a height of 150 feet, only a little above the tops of the trees, and on either side of the aircraft's flight path the hills were in cloud.

Conditions soon became misty and forward visibility worsened and, although flying just above the tree tops, the pilot had difficulty in keeping the railway in sight. Suddenly, directly in front of the aircraft, a tall tree materialized out of the mist. Too close to take avoiding action, the aircraft struck its topmost branches. The pilot quickly applied power and pulled back on the control column. The aircraft nosed-up steeply and plunged into the base of the cloud. Realising he could no longer control the aircraft, the pilot closed the throttle and called to his passenger to "hang on" as they were "going in". The aircraft stalled, and dived into the tops of trees 120 feet high, sliced its way through four cables of a power line 25 feet above the ground, then steeply banked to port, struck the trunk and lower branches of another large tree, eighteen feet from the ground. The wings and rear portion of the fuselage were torn off and the wreckage of the forward section of the fuselage fell to the ground and came to rest forty feet further on by the side of a road. The passenger extricated himself and the pilot was assisted from the wreckage by eye witnesses to the accident, who had run to the scene from nearby. Miraculously once again, both occupants escaped death and though they sustained serious injuries, later recovered fully.

The shattered wreckage of the Tiger Moth after its collision with the tree.





The site of the crash, just to the north-east of Bundanoon, was only nine miles from the site of the Tiger Moth accident 14 years earlier.

* * *

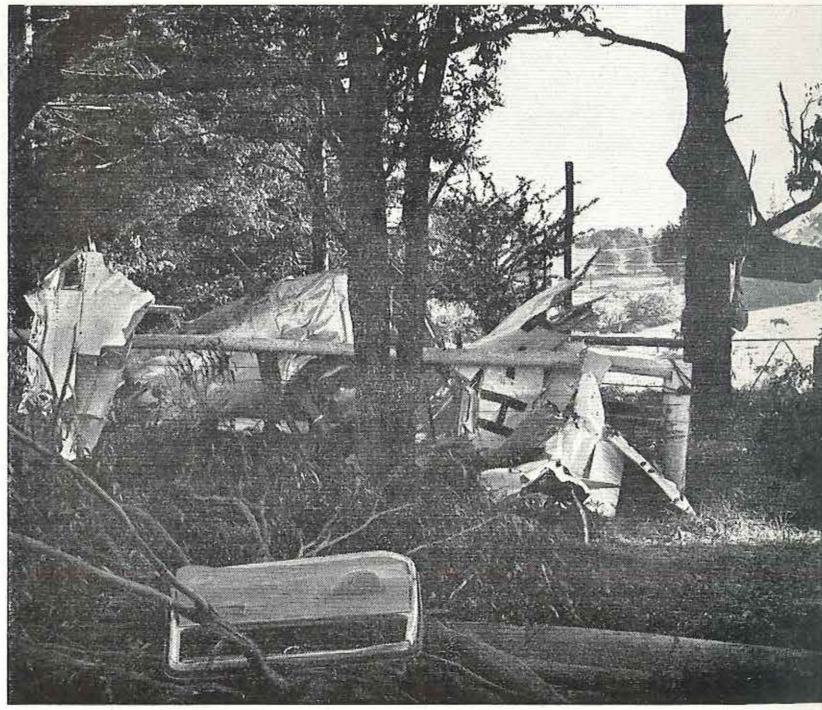
What is the message of these two accidents, whose circumstances are so remarkably similar? By all "the rules" the victims of these accidents should have been killed and had this been so, there would have been much less certainty as to the actual sequences of events that led to these accidents. The fact that neither accident proved fatal does not in any way mitigate the extreme danger to which these aircraft and their occupants were exposed in the attempts to continue visual flight in impossible conditions. Rather, it is just this happy state of affairs which enables us to examine (and we hope profit from) two disasters that were obviously going somewhere to happen.

Perhaps the most immediate reaction to a study of the circumstances of the two accidents is one of dismay — that in spite of 14 years of progress, development and operational experience in general aviation, accidents of this sort are still occurring. Indeed, if these particular accidents are any indication, the situation, if anything, has worsened. If any excuses are to be made, it is probably the private pilots of the Tiger Moth who are the less blameworthy. With their comparative inexperience, enthusiasm and youthful exuberance, their "press on" attitude, though not of course to be condoned, is at least understandable.

In the case of the Cessna accident however, the pilot was the holder of a commercial licence, professionally employed in a charter organisation in what is to-day a mature industry, and was carrying a paying passenger who had every right to expect a professional standard of conduct and safety. The attitude actually displayed by the pilot, in placing his aircraft in a situation where an accident was only a matter of time, is in sharp contrast to what should be expected, and raised grave doubts as to the pilot's capacity to exercise the degree of command judgement required of the holder of a Commercial Pilot Licence.

It is to be hoped that the lesson of these two accidents, building on those many less happy operational lessons of the intervening years, will forcibly demonstrate the utter foolishness of pressing on into obviously deteriorating conditions when all indications and every dictate of elementary airmanship urges one to turn back BEFORE IT IS TOO LATE.

Above and Below: The disintegrated remains of the Cessna 182 after it had crashed through the trees, struck a power line, and fallen to the ground. Note the rear fuselage caught in a fork of the large tree in the picture above.



FLIGHT OVER MOUNTAINS

(Adapted from Aeronautical Information Circular, published by Board of Trade, United Kingdom.)

SINCE the publication of the article "Mountain Wave Systems" (condensed from an earlier U.K. Aeronautical Information Circular on the same subject) in Aviation Safety Digest No. 42, June 1965, further research has added to the knowledge of the effect of high ground on the flow of air. The need for this research was emphasized by the fatal accident to the Boeing 707 which broke up in flight near Mt. Fuji, Japan, in March, 1966. The report on the investigation of this accident concluded that while flying near Mt. Fuji, the aircraft suddenly encountered abnormally severe turbulence, which imposed a gust load considerably in excess of its design limit. A summary of the report on this accident is published on page 10 of this issue of the Digest.

The purpose of this further article is to serve as a reminder of the basic theory of air flow over mountains and to include the new information that has become available. The article also discusses the effect of the airflow on aircraft in flight and offers advice on avoiding or minimising the hazards that may be encountered.

An airstream flowing over mountainous terrain is disturbed in a manner broadly analogous to the disturbances in a river flowing over a rocky bed, the ripples and scattered breakers on the river surface corresponding roughly to the mountain waves and turbulence often found above mountainous terrain. In general, the higher the mountains or the faster the airflow, the greater is the resulting disturbance.

In stable air conditions, the disturbance of a transverse flow of air by a mountain range, can create an organised flow pattern comprising waves and large scale eddies in which strong vertical currents and turbulence can occur. These effects often extend to very considerable heights above the level of the high ground. Wave disturbances occurring over mountains are referred to as mountain waves and, when similar disturbances extend for some distance over relatively flat ground to the lee of the mountain, they are termed lee waves.

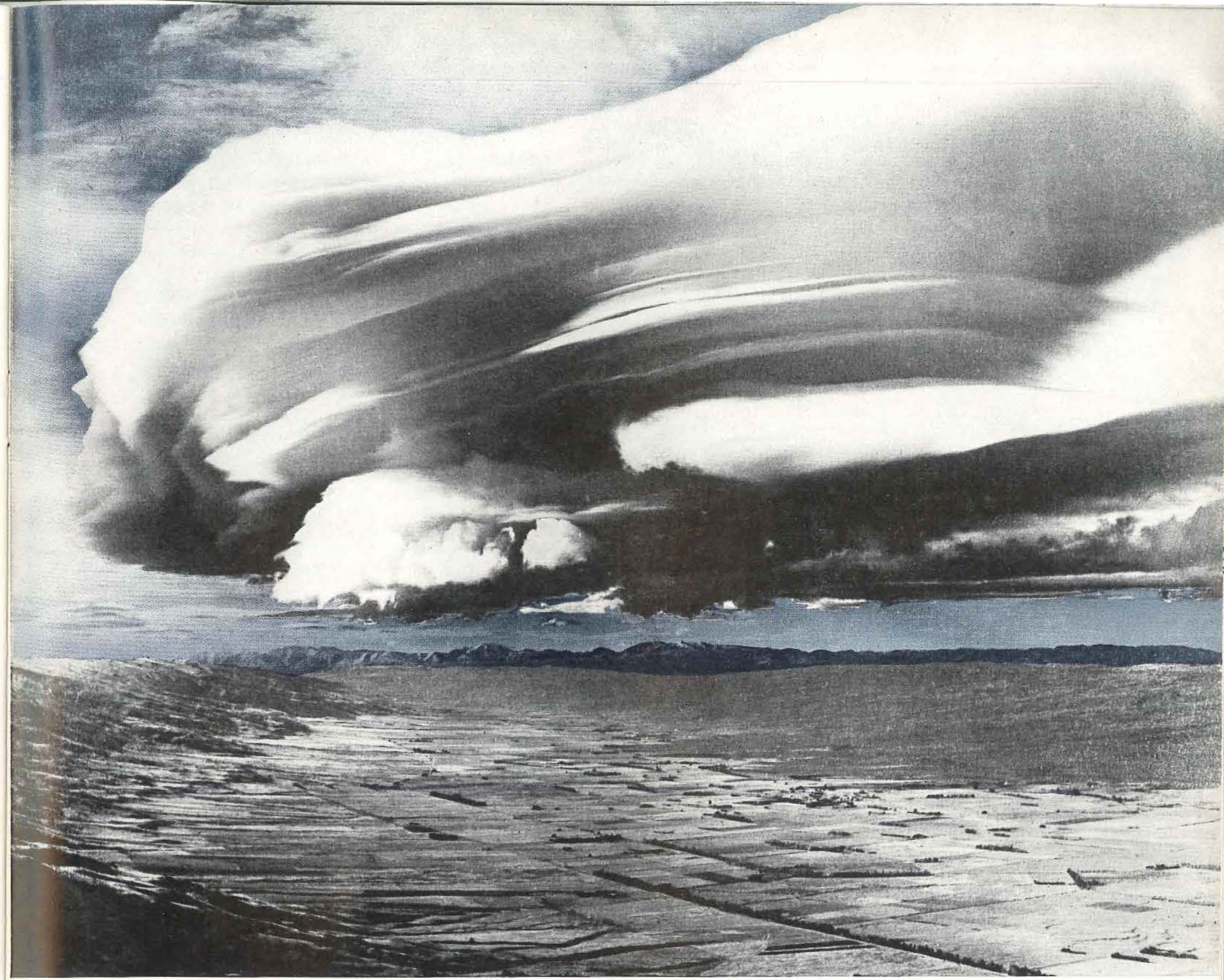
Meteorological conditions favourable for the formation of mountain and lee waves are:—

- A wind blowing more or less at right angles to a substantial ridge. A ridge with a gentle up-wind slope and steep down-wind escarpment is the most efficient generator of lee waves.
- A wind speed at crest level of more than about 20 knots, and the speed increasing with height, but with little change in direction. Strong wave conditions are often associated with jet streams.
- A marked stable layer somewhere between crest level and a few thousand feet above. This stable layer must be bounded by less stable air above and below.

Wave systems resulting from these conditions can extend well into the stratosphere, occasionally to 80,000 feet, for many miles down-wind of the initiating high ground, and will often persist for a number of hours. Satellite photographs have, in fact, shown wave clouds as much as 500 miles down-wind from the Andes, but 50-100 miles is more usual in most mountain wave systems. The average wave length of lee waves is about 5 miles but may be anything up to 30 miles. Generally, the stronger the wind, the longer the wave length.

The factors that determine the amplitude of the waves are more complex but this tends to be greatest if the dominant wave length of the mountain wave is roughly "matched" by the shape of the topography. The amplitude of the waves also tends to increase with the "amplitude" of the terrain. The speed of the vertical currents within the wave system depends upon the wave length, wave amplitude as well as the wind speed. Even over the British Isles where there is comparatively little mountainous terrain, vertical currents up to 35 ft. per sec. have been recorded, but values greatly in excess of this may occur near large mountains.

In extensive mountainous areas, the lee wave system generated by one ridge can be disturbed by other ridges further down-wind. Moreover, the characteristics of any given airstream are always changing slowly and there are likely to be occasions when a small change in airstream



WHITE'S AVIATION LTD. (AUCKLAND, N.Z.) PHOTO

Spectacular mountain wave cloud formations over the Canterbury Plains in the South Island of New Zealand. The clouds are lying in the lee of the Southern Alps, which can be seen in the far distance.

characteristics gives rise to a large change in mountain wave characteristics. Such a change, which is impossible to forecast, may generate transient but severe disturbances, resulting in violent turbulence (e.g. as the result of waves "breaking").

Detecting Mountain Waves

Particular types of cloud which owe their appearance to the nature of wave flow are a valuable indicator to the existence of wave systems. Provided it is sufficiently moist, the ascending air will produce condensation and formation of characteristic clouds. These clouds, which can occur at all heights from surface to cirrus cloud level, form in the crest of standing waves and therefore remain more or less stationary in relation to the terrain. These different cloud types are illustrated diagrammatically on page 25, which shows a characteristic distribution of clouds and turbulence in the lee of the Sierra Nevada, in the United States. This is an area in which mountain wave phenomena are exceptionally marked, but the diagram nevertheless has a fairly general application.

LENTICULAR clouds provide the most unmistakable evidence of the existence of mountain waves. They form within stable layers in the crests of standing waves while air streams through them, the clouds regenerating at their up-wind edges and dissipating down-wind. They have characteristically smooth, lens-shaped outlines and may appear at several levels, sometimes resulting in an appearance reminiscent of a stack of inverted saucers. Lenticular clouds usually appear up to a few thousand feet above the mountain crests, but are also seen at any level up to the tropopause and at times even above this. Air flow through these clouds is usually smooth unless the edges of the cloud take on a ragged appearance, indicating that turbulence is present.

ROTOR OR ROLL-CLOUDS appear at first glance as harmless bands of ragged cumulus or stratocumulus parallel to and down-wind of the mountain ridge. On closer inspection however, they are seen to be rotating about a horizontal axis. These clouds are produced by a local breakdown of the flow into violent turbulence and often occur on the crests of strong waves, but underneath the stable layers associated with the waves. The strongest rotor normally forms in the first wave down-wind from the ridge, and is therefore usually near to or somewhat above, the level of the ridge crest, but occasionally may be much deeper. Over the Sierra Nevada for instance, rotor clouds have sometimes extended to 30,000 feet. Usually there are not more than one or two rotor clouds in the lee of any one ridge.

CAP CLOUDS form on the ridge crest or mountain summit and strong surface winds, which are commonly found sweeping down the lee slope, may sometimes extend the cap cloud down the slope producing a "cloud fall" or "föhn wall".

Although cloud often provides the most useful visible evidence of disturbances to the airflow, it should be remembered the characteristic cloud types may sometimes be obscured by other cloud systems, particularly frontal cloud. On the other hand, there may be times when the air is too dry to form any clouds at all, even in strong wave conditions.

Turbulence

Although flights through stable mountain waves are often remarkably smooth, turbulence is likely to be encountered at any level in mountain wave systems and may on occasions be as violent as that encountered in severe thunderstorms.

ROTOR TURBULENCE: The worst turbulence encountered over mountainous terrain is usually found in standing rotors. Within these rotors, vertical velocities of up to 100 feet per second may occur which can cause structural damage or even the failure of an aeroplane structure.

LOW LEVEL TURBULENCE (i.e. within a few thousand feet of the mountain summit): A strong wind flowing over irregular terrain will produce general low level turbulence which increases in depth and intensity with increasing wind speed and terrain irregularity. Strong winds confined to the lower troposphere generally produce the most turbulent low level conditions, sometimes accompanied by "rotor streaming". In these conditions, violent low level rotors are generated intermittently near the lee slopes and move down-wind for a distance before decaying. These low level rotors are however, quite distinct from the stationary rotor zones found in wave crests at higher levels, which have already been described.

HIGH LEVEL TURBULENCE: Most public transport aircraft now fly at or near jet stream levels and evidence is accumulating that turbulence in jet streams often increases greatly in intensity and extent over mountainous areas, particularly in the vicinity of stable layers in the upper troposphere, e.g. the tropopause. The worst turbulence may occur just beneath stable layers, but it may also occur within stable layers if the wind shear is strong enough. Strong vertical wind shears are often concentrated in one or more stable layers a few thousand feet below a jet stream core and in the base of the stratosphere above. Although the cold side of a jet stream is known to be prone to turbulence, mountain wave conditions may be most pronounced on the warm side.

STRATOSPHERIC TURBULENCE: Recent evidence from research flying undertaken by the Royal Aircraft Establishment over the Rocky Mountains in America, shows that strong waves, sometimes with associated severe turbulence, may extend well into the stratosphere on days favourable for strong wave formation in the troposphere, and can cause serious difficulties to an aircraft flying near its ceiling.

TURBULENCE CAUSED BY CHANGING CONDITIONS: As already mentioned, changes in wave amplitude and wave length, resulting from changing airstream characteristics and interference between adjacent wave trains, can produce severe turbulence on occasions at any altitude. These disturbances will probably be transient and not necessarily stationary. Virtually nothing is known about them, either by observation or in theory, and they cannot be forecast, apart from a general indication that they are likely to occur anywhere over, and to the lee, of mountainous terrain in mountain wave conditions, particularly when marked changes in the upper air pattern are taking place.

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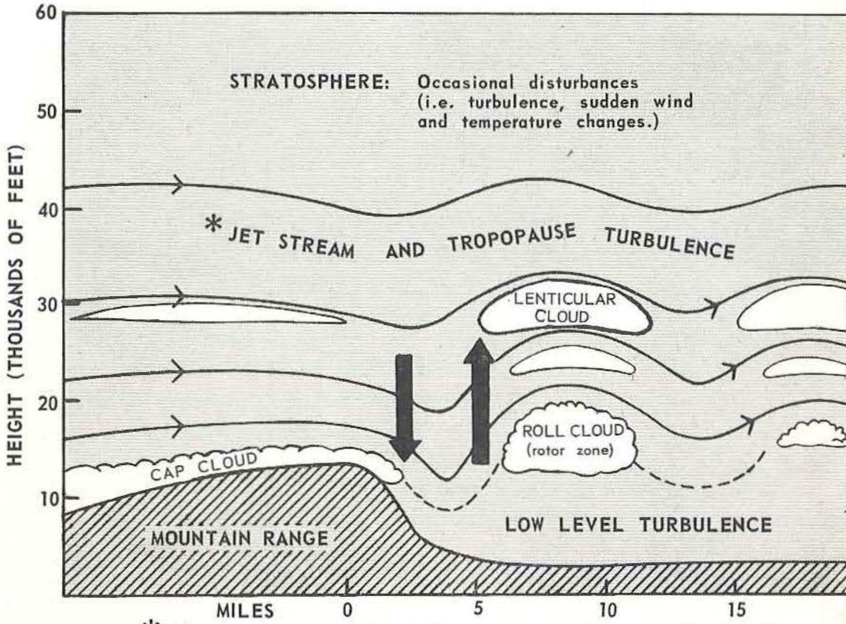
The effects that mountain waves will have on aircraft in flight depends to a large extent on the magnitude of the disturbance to the airflow, the performance of the aircraft, its altitude and its speed and direction relative to the wave system. A broad distinction may be made between mountain wave hazards at lower levels (below about 20,000 feet) and those at high levels (above 20,000 feet).

Lower Level Hazards

The main hazards to aircraft flying in mountain wave conditions below 20,000 feet are those arising from severe turbulence, particularly in the rotor zone, from down-draughts, and from icing. The presence of roll clouds in the rotor zone can warn pilots of the region of the most severe turbulence, but as already pointed out, characteristic cloud formations are not always present or, if they are present, may lose definition in other clouds. Similarly, up-draughts and down-draughts are not usually visible and an aircraft remaining for any length of time in a down-draught (e.g. by flying parallel to the mountains in the descending portion of the wave) could sustain a dangerous loss of height.

When an aircraft is flying up-wind through a mountain wave system its height fluctuations are out of phase with the waves and the aircraft is likely to be at its lowest height when over the highest ground. The pilot may also find himself being driven down into a roll cloud over which there previously appeared to be ample height clearance. In this respect down-wind flight through a mountain wave system is safer because height variations are normally in phase with the waves. However, the relative speed of an accidental entry into the rotor zone will be greater than in up-wind flight, because the rotor zone is stationary relative to the terrain. Thus structural loads imposed on the airframe when gusts are encountered are likely to be greater when flying down-wind and there will probably be less warning of possible handling difficulties.



* The tropopause and level of maximum wind are usually located somewhere within this layer

Diagram of a typical well developed Mountain Wave System.

Higher Level Hazards

The primary danger at high altitude is that of a sudden encounter with localised disturbances (i.e. turbulence, sudden large changes of wind, and temperature changes) at high penetration speeds. This is particularly relevant at cruising levels above 30,000 feet, where the buffet-free margin between the limiting Mach number and the stall is small. In this regard, flight down-wind is likely to be more critical than flight up-wind, especially when the wind is strong. As in the case of low altitude flight, the waves are stationary relative to the ground, and the higher relative speed while flying down-wind, is likely to place greater loads on the airframe if a standing wave is encountered. Similarly, there may be no advance warning of the presence of wave activity from preliminary oscillations or turbulence. Although down-draughts are present at these higher levels, they are unlikely to pose any hazard. An encounter with rotor zone turbulence is also unlikely.

* * *

Whatever the level of flight through strong mountain waves, large fluctuations in wind velocity may be encountered, with associated turbulence. It is possible for aircraft entering a wave system in these conditions with its auto-pilot, including the height and airspeed locks, fully engaged, to begin oscillating in the pitching plane, as the auto-pilot attempts to maintain the selected height and airspeed. This oscillation can become unstable and, if unchecked, result in the aircraft being placed in a dangerous attitude. A similar result may occur if the aircraft is being flown manually and the pilot "chases" height or airspeed. In either case there is the risk of an upset developing with catastrophic results, and in these conditions it is important to adhere to the well established technique of flying "attitude".

When mountain wave development *is* forecast or known to be present, pilots should take particular care not to penetrate rotor clouds or likely rotor zones adjacent to mountain ranges. In such conditions, an in-flight terrain clearance of at least 5,000 feet should be allowed above mountains that stand up to 5,000 feet above the surrounding terrain. For higher mountains, the clearance allowed should be at least equal to the height of the mountains above the surrounding terrain. Terrain clearances of this order should enable the worst of the lower altitude mountain wave hazards to be avoided. In the case of high flying aircraft, pilots should choose cruising altitudes well separated from the base of layers of marked stability, for it is there that severe turbulence is most likely to occur. When more than one stable layer is present, it is advisable to allow a vertical separation of 5,000 feet above or below the level of the tropopause.

Areas of turbulence associated with mountain and lee waves cannot be forecast with accuracy, but meteorological offices can usually help pilots to assess the probability of occurrence of mountain and lee waves, and assess the height of layers of marked stability. When planning a flight over mountainous terrain therefore, it is wise to consider the possibility of mountain wave conditions at the meteorological briefing, particularly if frontal conditions are present in the area and a jet stream is expected at altitude. Pilots should also pay careful attention to any warnings which may be given in SIGMET broadcasts in the course of their flight.

This Concerns You !

For many years past, the Aviation Safety Digest, Operational Documents, and other publications issued by the Department, have been addressed for distribution by an addressograph machine at the Department's Publications Production Centre in Melbourne.

With the tremendous growth of the Aviation Industry however, the stage has now been reached where this addressograph system is inadequate to cope with the volume of material being issued to the Industry. Arrangements are therefore being completed for this task to be handled in future by an electronic computer, which will also maintain a complete record of all licence holder's names and addresses.

With the introduction of computer addressing, all amendments to our records will be supplied to the computer by the Regional Offices in each State.

For this reason it is important that licence holders in future notify any change of address to their Regional Office.

The actual despatch of Departmental publications will nevertheless continue to be made from Melbourne, and any queries concerning their supply or non-receipt should be addressed, as before, to the Publications Production Centre, Department of Civil Aviation, Box 1839Q, G.P.O., Melbourne, 3001.

Questions or comments relating solely to the Aviation Safety Digest should of course, continue to be addressed to the Editor, Aviation Safety Digest, at the same G.P.O. Box number.

DON'T BECOME COMPLACENT ABOUT CLOUD

FOUR years ago this winter, four light aircraft together with all their occupants, were lost within a period of six weeks when the pilots allowed themselves to be trapped in conditions of low cloud and were finally deprived of all visual reference. The situations that led to these needless fatalities developed because, in each case, the pilots, who were not qualified for instrument flight, persisted in their attempts to continue in what were clearly less than Visual Meteorological Conditions. In each case the pilots, after becoming caught in cloud, became disoriented and their aircraft dived into the ground at high speed.

The tragic lessons of these so similar accidents, following so closely upon one another, left a deep impression on all who had the opportunity of studying their circumstances,* so much so, that with one exception, the intervening years have been free of fatal accidents arising from this cause.

Time is reputed to be a great healer however, and with the passing of the years there are ominous signs that the message of the unhappy events at Burketown, Ballarat and the Adelaide Hills, have been forgotten or, perhaps among those who are comparatively new to the aviation industry, never heard in the first place. In one week recently, for instance, no less than three light aircraft became caught in Instrument Meteorological Conditions and were forced to call for navigational assistance. It is fortunate indeed that in each case the pilots were able to maintain at least some control of their aircraft when suddenly deprived of visual reference. Had this not been so, there would most probably have been a repetition of the tragedies of 1964. Harsh experience shows that more often than not, disorientation and loss of control, with the inevitable final result, is the usual outcome of events when pilots with no instrument flying training are deprived of visual reference.

* See Digest No. 41, March, 1965.

These three most recent occurrences, though happily no more than incidents, nevertheless provide timely reminders of how easy it is to suddenly find oneself in cloud if a decision to turn back is not made early enough. For this reason, it is useful to examine the circumstances of each of the three incidents.

The first involved a private pilot flying a Mooney 21 from Essendon to Sydney. The pilot had obtained a forecast before departing and had planned the flight to cruise at 9,000 feet. While climbing after departure, the pilot saw there was a layer of cloud ahead with a base of about 5,000 feet. On reaching cruising level, the pilot found that its top was at about 8,000 feet and that its extent made it very doubtful whether visual fixes could be obtained at the requisite 30 minute intervals. The pilot therefore requested, and was granted a clearance to descend to below 5,000 feet. At first, visibility at this level was satisfactory, but after passing Yea, it began to deteriorate and the cloud base lowered progressively. Conditions worsened after the aircraft passed Strathbogie and the pilot decided to turn back, and advised Melbourne he was returning to Moorabbin outside controlled airspace. Descending gradually to remain below the lowering cloud base, the pilot found he was at 2,000 feet by the time he had reached Yea again, and was now flying in rain with a visibility of less than three miles. On the adjacent high ground the cloud was close to the hilltops, and knowing that higher terrain lay ahead, the pilot then decided he would have to make a spiral climb to 4,000 feet to ensure a safe terrain clearance. The climb took the aircraft into cloud and the pilot called Melbourne to report his flight condition. The aircraft was transferred to the Melbourne Approach frequency and after becoming visual further south, was vectored to Moorabbin Airport.

Two days later, another private pilot set out from his farming property near Bacchus Marsh, Victoria, to fly to Horsham 130 miles to the west.

The area forecast which he obtained by telephone before departing was not favourable and indicated a visibility of 10 miles, reduced to two in drizzle, five eighths of cloud at 2,500 feet, three eighths at 3,000 feet and five eighths of stratus in areas of drizzle.

Approaching the higher ground to the east of Bacchus Marsh, the pilot climbed to maintain a terrain clearance of about 1,000 feet. Near Ballan a few minutes later, the aircraft had reached 3,000 feet and encountered rain. Ahead, the pilot saw the cloud was almost at ground level, so be began to orbit while he watched the weather, hoping for some improvement. Instead however, the weather continued to deteriorate and the pilot then saw he was surrounded by low cloud reaching almost to ground level and that his height just below the cloud base was now only 500 feet above the terrain. The cloud continued to move in quickly and suddenly the pilot found he was in it.

The pilot called Melbourne for assistance, and using the artificial horizon to keep the aircraft laterally level, managed to climb back to 3,000 feet, but he was unable to keep the aircraft from turning. After informing the pilot that better weather existed to the south-east, Melbourne advised him to continue climbing until he broke out on top. This he did at 4,500 feet and soon afterwards was able to descend through a large break and make a safe return to the airstrip on his property.

The third similar incident occurred a few days later, when another private pilot was en route to Bacchus Marsh from a country aerodrome in northern Victoria. This time, the pilot had departed without first obtaining a forecast, because he had experienced a considerable delay in trying to contact Moorabbin Airport by telephone. He had however, telephoned his destination and ascertained that the weather was fine and clear there.

The flight was normal until soon after passing Kyneton when, with only 25 miles to run, the pilot saw there was low cloud ahead with poor visibility. He nevertheless continued for a few minutes, but when over rough country abeam Mt. Macedon, became concerned with the deteriorating conditions and decided to turn back. As he was turning, the aircraft entered heavy rain, the windscreen iced up, and the pilot found he was flying in cloud. The pilot called Melbourne Approach, advised his situation, and requested a radar vector to Bacchus Marsh, at the same time climbing the aircraft to gain terrain clearance. The aircraft broke out on top at 4,500 feet and, after carrying out an orbit for radar identification, the pilot was given a heading to fly. A little later, the pilot sighted Bacchus Marsh through breaks in the cloud and was able to make a visual descent.

It is evident that in all three cases, these aircraft, which were required to operate under Visual Flight Rules, entered cloud as a result of their pilots pressing on too far into deteriorating weather conditions. In each of these cases, the pilot either failed to recognize the trend the weather conditions were taking or chose to disregard these signs in the interests of completing his flight.

In the case of the Mooney which was finally forced to enter cloud near Yea, the pilot though he did not hold an instrument rating and was thus unauthorised to operate the aircraft in Instrument Meteorological Conditions, had nevertheless undergone a considerable amount of instrument flying training and was able to maintain control of the aircraft. In this situation however, controlling the aircraft is only half the problem. There still remains the task of navigating the aircraft accurately by reference to instruments, especially when, as in this case, the aircraft is in close proximity to a major airport and its associated controlled airspaces. The combination of the two tasks can prove too much for a pilot inexperienced in "real" instrument flying, which is a very different matter to flying on instruments under simulated conditions, with an instructor ready to hand.

Worse still, in the other two incidents, neither pilot had any instrument flying experience and once having entered cloud, were clearly in danger of losing control very quickly. Just how close one of the pilots came to this is evident from his admission that he was unable to maintain directional control while attempting to climb in cloud.

It is perhaps fortunate that while they were actually flying in Instrument Meteorological Conditions, no additional manipulative demands were made on these pilots and in the two latter cases there were apparently a sufficient number of breaks, or the cloud was sufficiently diffuse, for the pilots to retain a measure of orientation from sources outside the aircraft. Had the cloud in which they were caught been heavier and of greater vertical development, these events could easily have had a very different type of ending.