PRINTED BY HEDGES & BELL PTY. LTD., MARYBOROUGH

COMMONWEALTH OF AUSTRALIA

AVIATION SAFETY DIGEST

DEPARTMENT OF CIVIL AVIATION No. 15, SEPTEMBER, 1958

Aviation Safety Digest

No. 15 September, 1958

Prepared in
the Division of
Air Safety Investigation

CONTENTS

News and Views

Your Health and your Licence may depend on This!

(A Message from the Director of Aviation Medicine)

In May, 1957, an agricultural pilot when landing a DH.82 at the conclusion of a ferry flight, struck electric cables some 30 feet above the ground with his undercarriage. The aircraft, violently bunted by this impact, hit the ground nose-first in a near-vertical attitude. The relevant form C.A.462 (Aircraft Accident—Medical Report) records that when seen by a doctor one hour after the accident, the pilot had lacerations of the face and extensive bruising over the low back and buttock areas. The doctor could not exclude, on his clinical examination, the possibility of spinal or other bone or joint injury underlying the bruised area, and advised the pilot that x-rays should be taken. The pilot failed to take this advice, however; he left the district on the day of the accident, and was not seen again by the doctor.

Approximately a fortnight after the accident, the pilot underwent routine medical examination for renewal of his commercial pilot licence, by an authorized examiner in another district. He told the examiner of his accident, but mentioned "cuts on the face" as his only injury.

When renewal of the pilot's licence again fell due, in June, 1958, he presented himself to another authorized medical examiner. It was then revealed that subsequent to renewal of his licence in June, 1957, the pilot had developed symptoms related to his lower spine, and that x-rays ordered by a specialist he consulted had shown a fractured vertebra in this region, and indicated that an inter-vertibral disc adjacent to this vertebra was disrupted. One result of this was that portion of the sciatic nerve — the major nerve supplying the leg — was subjected to constrictive pressure near its site of emergence from the spinal cord, this producing pain, and abnormalities of muscular control and of reflexes, in the limb. Apart from its immediate undesirable effect on the subject's efficiency as a pilot, this condition is serious in that the longer it is allowed to persist, the more likely does non-reversible damage to the nerve, and hence to function of the limb, become. Early and adequate treatment of injuries of this type is most important, if a satisfactory result is to be achieved.

Certain treatment had been given in this case, including provision of a spinal brace to support the lower spine and thus ease the pressure on the sciatic nerve; this brace was still being worn when the pilot presented himself for renewal examination. That the treatment had not been entirely successful was shown by the elicitation by the examiner of clear signs of a persisting "active" intervertebral disc rupture. The resulting situation is that the pilot is assessed by D.C.A.'s Division of Aviation Medicine as at present medically unfit for licence renewal.

Several important points emerge from a consideration of this accident and its sequel. The first is that the pilot did not ensure that he was properly medically cleared after the accident; this failure later rebounded on his own welfare. The second point is that he failed to provide, to an authorized medical examiner, some fortnight after the accident, a full statement of injuries incurred, as far as these were then known to him. He nevertheless signed a declaration on his C.A.231 (Medical Report Form) that to the best of his belief the statement he had made was complete and correct. The penalty for such a false declaration may be refusal or cancellation of licence, or prosecution. The third point is that, on finding it necessary at a later date to obtain medical treatment, including the prescription of a spinal support, for the sequel of his accident, he presumably continued to fly, and failed to notify his incapacity to the Department of Civil Aviation, as unequivocally required by Air Navigation Regulation 58, and Air Navigation Order, Part 40.0.8.

By failing to observe medical advice given on the day of his accident, and by his subsequent errors of omission and commission, this pilot has now placed himself in an invidious position both medically and legally. This case would appear to illustrate the fact that failure to observe regulations, the spirit of which is to assist rather than obstruct the efficient and safe conduct of the industry and the well-being of its personnel, may be fraught with undesirable consequences for the individual concerned.

In order that it should not be thought that the case described above is an isolated occurrence, the following brief account of another case very similar in a number of its features, is given. In April, 1955, an agricultural DH.82 pilot aborted a take-off from a short field when it became apparent that the aircraft would fail to become airborne in the distance available. The aircraft straddled a channel about 8 feet deep at the end of the field and was extensively damaged. The pilot did not report any personal injury and did not seek a medical check. On medical examination for renewal of his licence, some four months after the accident, the presence of a fractured vertebra in his lower spine was disclosed, and he then admitted that he had been suffering severe backache. The examiner recommended that a spinal support should be worn for some time. Renewal of the licence was refused on medical grounds.

This pilot is now, more than three years after the accident, seeking revalidation of his licence, and is believed to have stated that only now does he consider himself sufficiently physically fit to pass a medical examination. The report on this examination is not yet to hand.

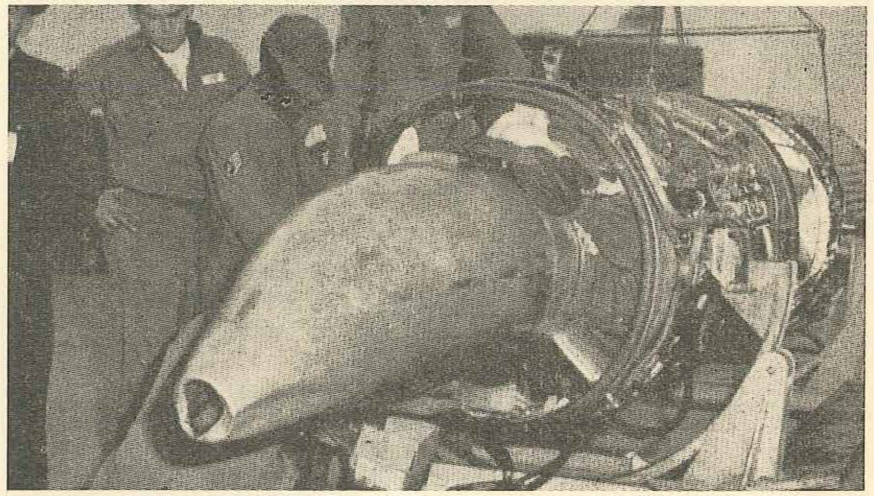
It is abundantly clear in this case that the pilot's interests would have been well served by undergoing a post-accident medical check, which in all probability would have led to discovery of his spinal injury, and prompt prescription of corrective treatment. Failing this, it must surely be regarded as folly that, on developing severe backache after the accident, he did not seek advice as to its cause.

It will be readily conceded that good engineering practice demands that an airframe which has suffered in an accident structural stresses probably beyond its design limits should be checked for hidden damage (such as, for example, a cracked spar), even though no significant external damage is present. It would appear reasonable, therefore, to assert that a pilot's frame which has been subjected to structural overloads through rapid deceleration should be checked for occult damage —for "cracked spars" such as the fractured spinal-vertebrae discussed above. It can only be concluded that if a pilot fails to have his bone structure certified after an accident of any violence the time has then surely arrived to seriously question his competence to discharge the responsibilities imposed by his licence.

The Big Gulp

(Extract from "Aviation Mechanics Bulletin" May-June, 1958)

All these stories about the jets gulping up mechanics, swallowing fully grown men! Did you ever wonder how many of them are true and how many are just scarey, hairy, fairy tales designed to keep apprentice mechanics inside the hangar washing parts?



You can stop wondering. Although much of the evidence has been buried, it is conclusive. These yarns aren't yarns. They are reports. They do involve the military, but civilian jets will act the same way. The suction created by jet engines is terrific—and deadly. A check made to prove this point can lead to trouble.

Before attemping to cross in front of an aircraft on which he was working, an airman stuck his hand in front of the intake, evidently to see how much suction there actually was. He was jerked into the intake immediately, losing his life.

Loose clothing adds to the hazard, so personnel working in cold weather areas must watch their step in icy and snow conditions. One fortunate Air Force mechanic who lived through his Jonah experience will never forget this.

He was descending a ladder and slipped when he touched the ice and snow, falling towards the intake. He was forcefully yanked into the duct. The parka he was wearing helped protect his head and body; however, by being unfastened and loose, it may have been the cause of his being pulled into the duct.

The Navy has had its incidents, too. A report datelined April, 1958, told how a carrier-based mechanic was "shook up but good".

An F2H-3 had been given the light-off signal prior to launching. After light-off and a cockpit check, the pilot checked to the rear of the aircraft and requested a full turn-up.

While the aircraft was turning-up at 100% rpm, a mechanic went under the wing and unplugged the external starting power-leads. He came out in front and to one side of the starboard intake. As he straightened up, he was sucked into the intake, hitting his head on the butterfly valve. He held on with both hands and kept his eyes shut. The pilot noted a drop in his starboard rpm to 80% as two men grabbed the mechanic's ankles and tried to pull him out of the intake.

As the pilot was being given the "cut" signal by the director, he saw the man in the intake. Both engines were secured, and the mechanic rescued, suffering only minor injuries. It was real nice those men were there and grabbed his ankles.

Many mechanics have not been as fortunate. In January an experienced crew chief of a Strategic Air Command base was sucked into a B-47 engine. His injuries were fatal. Since then, at another base, another mechanic was killed in a similar accident. His crew was pulling an engine performance check with the engine running at 100%. He crossed in front of the intake and was immediately sucked into the duct. Although the engine was shut down and he was pulled out within minutes, he died of major injuries.

Take our word for it, and the word of the Air Force and the word of the Navy. Those gruesome stories are true! BOTH ends of a jet are dangerous.

Clues to Calamity

(Reproduced from "The MATS Flyer", February, 1958)

There is a saying to the effect that coming events cast their shadows before. So it is with many accidents—and all too often the price of accident avoidance could have been recognition of warning signs.

"Contact", called the copilot.

The aircraft commander swept his gaze across the lower part of his side window. He was bringing one more aid into his cross check—the ground—if he could see it.

A scud of rain-pushed cloud cut off the brief glimpse the captain had of lights. Rapidly he rechecked his instruments. One hundred feet to minimums. Heading and airspeed good. He eased on down. The on-off reflection of the navigation lights flared regularly in the mist, then stopped.

"See anything?" asked the pilot.

"We're in and out now . . . there . . . red lights . . . must be approach lights . . . take a look", the copilot replied.

The captain eased back on the wheel. They were almost at minimums. His right hand was on the throttles. He made a sudden break from instrument cross checking and leaned forward, peering intently through the windshield. They were below the clouds, but rain cut visibility sharply. The glow of blurred red lights showed off to the right and instinctively the captain pushed right rudder.

"A road! A road and buildings! Pull up! Pull up!" The copilot yelled.

The engines roared as the captain slammed the throttles forward. The altimeter showed 100 feet. Desperately he hauled back on the yoke.

Analysis

Maybe it didn't happen just this way. No one will ever know for sure. But circumstantial evidence pointed to just such a series of events. Seasoned pilots, piecing the evidence together, are in general agreement as to what must have happened.

The ceiling was ragged. Moderate to heavy rain was falling. A civilian coming out of his garage caught a glimpse of the plane. "Just above the rooftops" he estimated. He recalled hearing a "sudden roar of motors".

A Familiar Pattern

Accident files and pilot's accounts of "close ones" leave little doubt that the events depicted above have been enacted and re-enacted.

But some pilots claim they have never experienced a near accident. Since they operate the same equipment, over the same routes and face the same elements—WHY?

One reason, probably THE reason, is that they are able to recognise signs of danger.

In the above instance the clue might well have been "contact".

When are you contact? Surely not simply when you can see the ground. Not even when recognizable terrain features pass beneath your wings.

Contact conditions can only exist when identifiable terrain features can be clearly seen far enough ahead to permit necessary manoeuvring of the aircraft by reference to these terrain features.

The fact that the copilot called "contact" was surely a contributing factor in this fiasco. (But after-the-fact apportionment of blame by those who have hours instead of split seconds to reach decisions is hollow consolation.)

Rules of safe flying dictate that until contact conditions are definitely ascertained, instrument flight must be continued. Visual reference should be brought into the cross check, but only as a secondary aid. Also, let down procedures, minimums and missed approach procedures are clearly spelled out in flying regulations. There is no such thing as half IFR—half VFR flight. It must be one or the other, and in case of ANY doubt it must be IFR.

Here was a "sign" that was missed. Instead of promptly executing a go-around at minimums, the captain and his copilot were both TRYING to fly VFR.

Instrument Signs

For several days pilots had written up a suspicious cylinder head temperature reading. Corrective action was concentrated on the gauge, wiring to the gauge, terminal connections . . . (the same old routine). Finally, because the gauge had been telling the truth, the engine had to be feathered in flight.

This was another "sign". It was recognized, but obviously not properly interpreted.

This next incident exposes an even greater crime.

The crew detected smoke coming from the nose gear actuating cylinder area. Apparently the hydraulic fluid had heated up considerably for some unknown reason.

This crew didn't bother to write up their observation in the Form 1.

The next crew to take the plane up accomplished airwork, then made a practice GCA. At least three checks for gear down and locked were made on final. Touchdown was accomplished, and after the nose wheel touched the runway the pilot started to reverse the propellers. Right then things became anything but routine.

Gear position indicators showed unsafe.

Red gear warning lights flashed on.

The warning horn screeched out its fateful message.

One guess—yes, the nose gear collapsed.

Near Miss

And here's a little episode that resulted in neither incident nor accident, but will not be soon forgotten by the pilots involved.

A crosswind of 18 knots, with gusts above 30, required that the AC hold a crab coming down final. The runway lights were clearly visible from five miles out. The approach was being made with half flaps, in moderate turbulence. The copilot was calling airspeeds.

"One fifteen", then quickly, "one ten".

"Manifold . . . " The AC stopped when he heard the copilot call . . .

"One twenty five".

The pilot wrestled the controls to keep lined up on the approach. "No more flaps in this stuff", he ordered.

"One fifteen . . . one ten . . . one oh five."

"Manifold three five."

"One tweny five . . . she's O.K" the copilot sang out as a gust caught the plane again.

The engineer, who had started forward with the throttles, stopped when he felt the AC's restraining pressure and heard him say, "O.K. —hold power as is".

Almost too late the pilot felt the plane sink and at the same time heard the copilot report rapidly, "One fifteen . . . ten . . . five".

He made his flare at the last possible moment and hit hard on the green lights imbedded in the runway threshold.

Aided by the strong surface wind, turnoff was made easily 3,000 feet down the runway. (Four thousand feet of perfectly good blacktop remained.)

This pilot chalked up a near miss —a near miss of a landing short accident. (We've had them before.) He had missed "signs" all the way down the approach.

Top This

And among our flying brethren who ignore "signs", surely the most flagrant are those who land gear up. To accomplish this bit of expensive foolishness they must:

1. Fail to check gear position indicators.
2. Remain deaf to the raucous wail of the warning horn.
3. Ignore red warning lights. And frequently they must also:

Chop power much farther than normal to alight anywhere near the first third.

Fail to hear and heed pleas of the tower operator.

Fail to see a red flare, light gun, or both.

Signs of Safety

More properly these same clues to calamity could be called signs of safety. Reflect, if you please, on some samples:

The mechanic who always re-checks his work.

The supervisor who takes NOTHING for granted.

TCC officers who habitually visualize situations from the cockpit viewpoint.

Weather forecasters who are so appreciative of pilot reports.

The navigator always alert for hail bearing protuberances on radar.

The pilot-copilot team that always check each other on station identification.

Loadmasters consistently verifying weight and balance.

Methodical, complete preflighting of aircraft.

Personal equipment specialists always looking for frayed, worn and damaged equipment.

Checking all omni stations aurally.

Maintenance supervisors carefully studying engineers' logs.

Engineers frequently scoping their engines.

. . . But a list like this is endless.

CONCLUSION

Just as the flight surgeon is charged with noting and acting on clues to calamity from a medical standpoint, all of us connected with aviation have a like obligation.

If you need further convincing, become an unofficial accident investigator for a few minutes. Think back on any accident you may know of. (The more familiar you are with the circumstances the better.) Chances are more than one "sign" will stand out. Or re-analyse one of your own "close ones". All too often, far enough in advance to have permitted avoidance, there was a clue to forthcoming calamity. But is was missed.

BE YOUR OWN ACCIDENT ALERT OFFICER. *YOU* BENEFIT

Think, then Trim

(Extract from "Aviation Mechanics Bulletin" May-June, 1958)

Trim devices of various sorts are used to control the balance of an aircraft so that it will maintain straight and level flight without undue pressure on or displacement of the cockpit controls. Without trim devices a pilot would find it quite a problem to keep his bird flying straight and level as he operated at various airspeeds with varying CGs, due to fuel consumption, passenger shifts, etc.

These trim devices vary as the design of the aircraft dictates. The design which will do the trick on an L-5 isn't going to do on an irreversible power control system in present high-speed aircraft. This is why we have different systems of trim, such as fixed trim tabs, adjustable trim tabs, servo tabs, and trim devices which change the geometry of the control system to produce the proper control surface change. Each aircraft designed has its own way of setting trim. However, an aircraft which may be flown straight and level and with a minimum of pilot fatigue is the end result. Control operation is also kept within the physical limits of man.

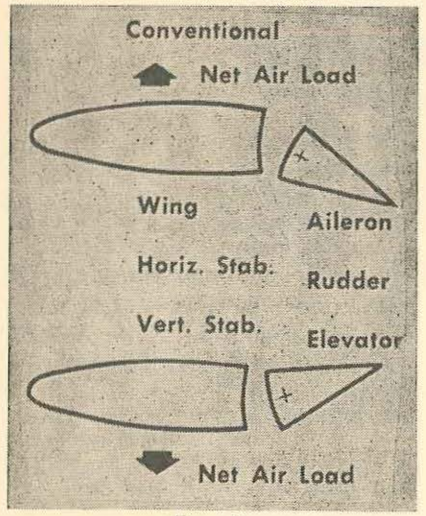


Fig. 1

Today we have two ways of making a trim change in our aircraft. The most common and unsophisticated method is to change the lift characteristic of the airfoil by changing its camber. This can be done to the wings or the tail surfaces by movement of ailerons, rudder and elevators. As can be seen in Figure 1, the movement of the control surface will either increase or decrease the net air load acting on the airfoil. To obtain this movement, trim tabs are employed. The tab does to the control surface precisely what the control surface does to the wing, vertical fin and horizontal stabilizer. The tab gives us a means of producing control surface deflection, which in turn changes the net air load acting on the airfoil.

By the way, what is camber? Camber is the convexity of an airfoil. It is the rise of the curve of an airfoil section from its chord. From this definition it is safe to say that we produce control surface camber as shown in Figure 1.

A look at Figure 2 will show that a trim tab has been added which may be used to change the control surface. The tab air load

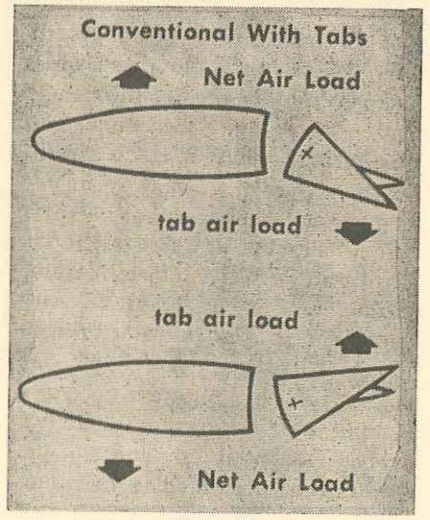


Fig. 2

produced is in the opposite direction from the air load of the main surface and was produced by moving the tab in the direction opposite to which we want the control surface to move. Got it? The control will go in a direction opposite to tab movement.

With irreversible control systems, trim tabs would have no effect in repositioning the control surface. For proof of this, try to move a power-boosted, irreversible control surface by pushing it with your hand while system power is ON. To trim an irreversible control, you reposition the entire surface by changing the control system geometry. Now, when you trim, you have to remember that actuation of the trim system will result in repositioning of the control surface itself. With irreversible controls the surface is trimmed in the direction it is to go, while with the trim tab system the tab will go opposite to the desired control surface movement.

Up to this point we have been getting our directional change by

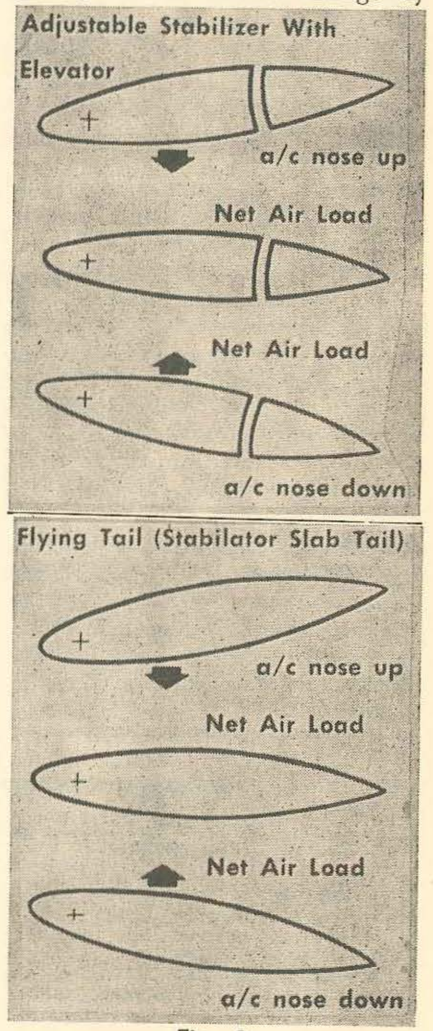


Fig. 3

varying the camber of our flight surfaces to establish trim change. Another way to trim the aircraft is to change the angle of attack of the horizontal stabilizer or vertical stabilizer. As the angle of attack changes, so will the lift of the airfoil. A look at Figure 3 will reveal which way the stabilizer or stabilator must be moved to produce a change in air load. The leading edge of the surface will move in the direction opposite to the nose of the aircraft.

When this trim system is checked, a good deal of confusion is created as a result of inadequate co-ordination between the man in the cockpit working the trim and the man on the ground checking control movement. If the man in the cockpit calls "nose down", it must be understood by the checker which "nose" is being referred to—aircraft or control surface. It is very easy for a man to hear "nose down" and then see the nose of the stabiliser go down and not realise the error that exists. Perhaps it might help if the man in the cockpit called:

"AIRCRAFT nose down" and
"AIRCRAFT nose up",
while the checker would call back:
"STABILISER nose up" and
"STABILISER nose down."

In checking a trim system, the checker must know what effect he is trying to produce on the aircraft and what must be done to gain this effect. Perhaps the chart may be of aid if clipped out and saved.

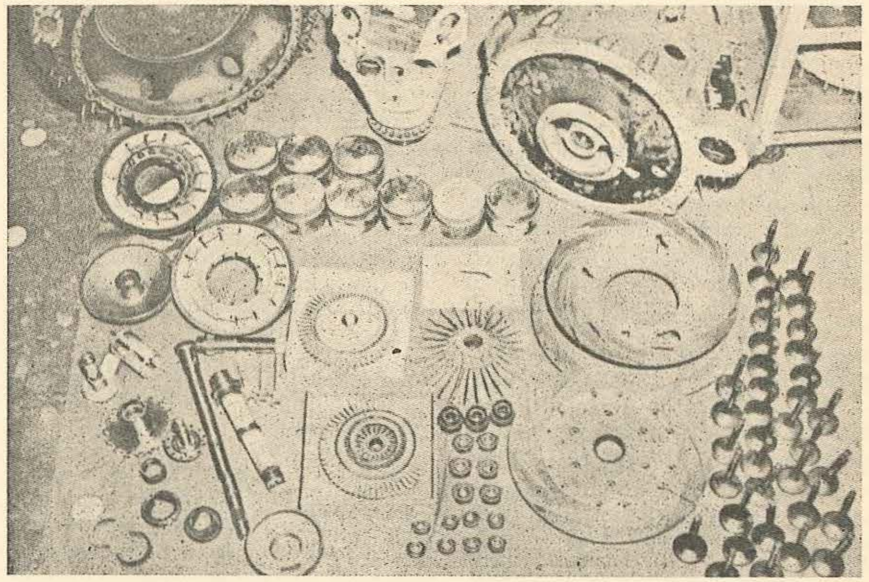
Remember, in today's aircraft, the trim is being used as a primary control device. The life of an aircrew and the completion of a mission will depend on the proper response from the aircraft trim system. Know what is expected of your aircraft's trim system. Don't set the stage for an accident.

A GUIDE FOR CHECKING TRIM DEVICES

to obtain	with TRIM TABS, tab should go	with IRREVERSIBLE CONTROL SURFACES, trailing edge should go	with FLYING TAILS, SLAB TAILS, STABILATORS, ADJUSTABLE STABILATORS, etc, surface nose should go
aircraft nose DOWN	UP	DOWN	UP
aircraft nose UP	DOWN	UP	DOWN
aircraft nose RIGHT	LEFT	RIGHT	LEFT
aircraft nose LEFT	RIGHT	LEFT	RIGHT
left wing DOWN	DOWN (left tab)	UP (left aileron)	
left wing UP	UP (left tab)	DOWN (left aileron)	
right wing DOWN	DOWN (right tab)	UP (right aileron)	
right wing UP	UP (right tab)	DOWN (right aileron)	

20,000 Dollar Cotter Key Extractor

(Extract from "Aviation Mechanics Bulletin" May-June, 1958)



Nestled here in the centre of the engine parts it destroyed is a cotter key extractor that caused big trouble. According to the records the R-3350 engine involved operated 107 hours after it was overhauled. Some time during the period the cotter key extractor sneaked into the air scoop and started things grinding.

It damaged the blower section, two power recovery turbines, the tail-shaft, nine pistons and numerous gears. The damage plus labour amounted to $20,000.

Since screens are not installed in R-3350 carburettor air scoops it is most important to keep tools and foreign objects out of the area.

See and be Seen?

(Extract fromAccident Prevention Bulletin 58-4 dated April 15,1958)

There have been many rumours about this incident, but here it is from an authentic source:—

"The pilot of a jet bomber was flying at 30,000 feet on a clear morning. He made a slow turn and was startled to see three other bombers approximately one mile away and on a collision course with him. Before he could react or alter the course of his aircraft, he shot through the formation, missing the nose of the first aircraft, flying under the second, and over the third. As he went over the third bomber, one of his engines struck the upper part of this bomber's tail and knocked it off. The pilot who flew through the formation then returned to his home base, landed, and recounted his experience. Inasmuch as no report had been received from the formation he had flown through, it was recalled and requested to land. When it landed it was found that the formation consisted not of three aircraft but of six. The aircraft whose tail had been hit was not significantly damaged. What is amazing is that neither the pilot, the copilot nor the observer in any of the six aircraft had seen the other bomber fly through the formation!"

Overseas Accidents

Viscount Crashes during Landing Approach

(The following is the substance of the report of the Court Investigation of the accident to Viscount G-ALWE which occurred at Ringway Airport on 14th March, 1957.)

Early in the afternoon of the 14th March, 1957, the Vickers Viscount aircraft G-ALWE (generally known as W.E.) crashed while approaching to land at Ringway Airport, Manchester, U.K. The aircraft was owned and operated by British European Airways Corporation and was reaching the end of a scheduled passenger carrying flight from Schiphol Airport, Amsterdam, with a crew of five and fifteen passengers. As a result of the accident all the crew and passengers and two other persons were killed.

At about 1334 hours on 14th March, 1957, the aircraft on its way to Ringway Airport passed into the control of the Manchester Approach Controller. At 1336 the approach controller received a call from the pilot and asked him to report passing Oldham Beacon and reaching 3,500 feet. The approach controller then gave him the latest weather observations—wind $250^\circ/23$ knots, visibility 10 nautical miles, cloud 5/8ths at 3,000 feet and 8/8ths at 10,000 feet. He also gave the aerodrome pressure. At 1341 the aircraft reported at Oldham Beacon still over 3,500 feet. (According to the normal practice the pilot would start his pre-landing drills after passing Oldham Beacon and this would include lowering the flaps.) The approach controller asked the pilot if he wanted an instrument let-down. The pilot said he would like GCA to give him a cloud break. This meant that he wished for the system of Ground Control Approach to be used so as to ensure a clear descent path, leaving him to make a visual approach after he had broken through the lowest cloud. He was accordingly handed to the GCA Director until he came below cloud and had the airfield in sight, when he asked to be transferred to the Aerodrome Controller. The pilot then gave a call meaning "finals", i.e., that he was in line of approach onto the runway in a position from which a landing would be made on his then present heading. The Aerodrome Controller told him he was clear to land and gave him the surface wind.

The Aerodrome Controller sighted the aircraft when it was $4\frac{1}{2}$ to 5 miles from the runway and the Approach Controller 3 to 4 miles. Both watched it approach (though neither was watching it continuously) and neither saw anything unusual until it was, they thought, about 1 mile or a little more from the end of the runway. Then both saw it take a gradual turn (one of them described it as a "shallow diving turn") to the right, which looked like an intentional manoeuvre, perhaps to get into line with the runway, but very soon the turn tightened up and the angle of the bank increased so that both these witnesses realised that something was wrong and each separately gave the crash alarm. Neither saw the actual crash because their view was obscured by buildings. The time of the crash was 1346. The time between the steep banking turn and the crash was estimated at something between ten seconds and half a minute. The airspeed at the critical time is estimated at 115 to 120 knots.

There were five eyewitnesses apart from the two Control Officers. All of them lived or worked in the neighbourhood and were familiar with the sight and sounds of aircraft coming in to land. Two of them in particular (one of whom, Mr. Stanford, had been a pilot in the R.A.F. from 1939 to 1946, and the other, Mr. Pettigrew, had had experience in the A.T.C. and as an observer at Farnborough and held a gliding licence), gave remarkably detailed accounts of what they observed. The evidence of the five witnesses did not exactly tally in all respects but there was general agreement that the aircraft was approaching normally (though perhaps rather lower than usual and perhaps on a heading which would have brought it rather to the left of the runway), until it reached a point about a mile from the threshold. It then banked to the right and maintained this bank for a few seconds. Mr. Stanford thought it side-slipped and looked as if it was getting into difficulties but then put on full left rudder and got on to an even keel. No other witness observed this. If there was any recovery it must have been only momentary because to other witnesses the aircraft appeared to pass straight from what might have been a controlled banked turn into a steep and uncontrolled turn. (One witness, but only one, said that the engine noise increased in loudness and rose in pitch.) The ultimate angle of bank was variously estimated at from 45 degrees to 80 degrees and then two of the witnesses saw the starboard wing tip touch the ground. From marks afterwards found on the ground and from pieces of wreckage collected, it can be stated positively that the starboard wing tip touched the ground about half a mile from the threshold and 150 yards to the right of the extended centre line of the runway. From that point a furrow in the earth made by the starboard wing went nearly straight (at an angle of about 45 degrees with the extended centre line) but curving very slightly to the right for a distance of about twenty-five yards and then, after a break of about ten yards, for about another thirty-five yards. During this time about half the starboard wing broke up and parts of it were found scattered to right and left of the furrow. The final crash which was into houses was about eighty-five yards from where the wing first touched the ground.

A most important piece of evidence was given by Mr. Pettigrew. He said when the aircraft was over a point which is rather less than a mile from the threshold and was perhaps five hundred to six hundred feet high, he could see it from directly astern and observed that the two inboard starboard flaps appeared to rise above the wing. It appeared to him that the centre joint between these flaps had come adrift from the wing. One moment the flaps were normal and the next they were bent. The angle of the flaps made it appear that they had risen above the trailing edge of the wing giving "a sort of roof effect". The port flaps remained normal. It was immediately after the movement of the starboard flaps that the aircraft first banked to the right. He looked to see if the ailerons moved but could not see any movement. I am satisfied that Mr. Pettigrew's observation of the movement of the flaps was accurate and, although it cannot be certain that he would have noticed any movement of the aileron if they had moved (because they are much smaller than the flaps), it can at least be said that there is no evidence from any eyewitness that the ailerons were operated at all after the first turning and banking movement began. Mr. Pettigrew estimated the time interval between the bending of the flaps and the final impact with the ground at only about five or six seconds. From the evidence of other witnesses I think that this is an under estimate and that the period was probably about twenty seconds.

As will appear later in this report a movement of the flaps such as was described by Mr. Pettigrew would tend to cause the aircraft to make a banked turn to the right but not to such an extent that the movement could not be easily controlled by the ailerons if they were working normally. Witnesses with experience in the control of aircraft all agreed that a competent and experienced pilot would automatically use his ailerons in such circumstances and I am advised by my Assessor, Captain White, that this movement would come so naturally to a pilot that it is unthinkable that he would not make it. This at once creates an impression that for some reason the ailerons must have been incapable of movement. If this was so then as appears from the evidence and the advice of my Assessors the only possible hope of getting the aircraft righted was by use of left rudder and increased power from the starboard engines. There is as indicated above some evidence that the rudder was put to port and there was some increase of engine speed. If these actions were taken in the very short time available then the pilot acted with great skill and promptitude but in all probability the bank was too steep and the aircraft too near the ground for these measures to be effective. Captain Gordon-Burge, a Senior Inspector of the Accidents Investigation Branch, expressed the opinion that there was nothing the pilot could have done to avoid the accident and I am satisfied that this is correct.

As already mentioned, the crash alarm was given by the two air traffic control officers independently before the aircraft struck the ground. Indeed, the airport fire appliances were on the move before the crash occurred. Five fire appliances, two foam tenders, two water tender/pumps and a Vauxhall tender were turned out. At about the same time two Fairey Aviation appliances, a pump tender and a Land Rover set out from the nearby Fairey Aviation Works fire brigade. All the abovementioned appliances reached the scene by 1350. At 1348 a call was made by direct telephone line to Altrincham Fire Station and within a short time twenty-four appliances were despatched from this and other stations. Also at 1348 Manchester Ambulance Headquarters were telephoned and sixteen ambulances and two shooting brakes were sent out. Further ambulances were called from other centres a little later. The Manchester City Police were called at 1351 and fifty Manchester police officers attended, also officers of the Cheshire County Police. Eight Ministers of Religion attended. Others who came quickly to the scene were hospital services (five doctors, one nursing sister, five nurses), airport technicians, Civil Defence (Rescue), Gas, Water and Electricity Undertakings, representatives of the Manchester City Surveyor's Department and two Morticians. There were also a number of civilian volunteers.

The aircraft had crashed into Nos. 23 and 25 Shadow Moss Road, Wythenshawe. It had apparently struck the houses below roof level, the wings had folded inwards, the fuselage collapsed and concertinaed and the wreckage buried itself beneath the roof debris of the houses. House No. 21 had also been severely damaged. The aircraft was upside down. Fire broke out in about twenty places.

Seven pump jets were got to work while the airport fire officer searched house No. 21 for survivors. More pump jets arrived and were got to work, followed by waterspread jets. Service and civilian helpers helped to remove debris and searched for passengers and crew and any residents in the houses. Between 1520 and 1910 twenty-two bodies were found, corresponding with the five crew and fifteen passengers known to have been in the aircraft and two residents ascertained by police enquiries to be unaccounted for in the houses. The operations were substantially complete by 1944 but smouldering debris was still being dealt with up to 2321.

It is clear the mobilisation of all necessary services in adequate numbers was carried out with promptitude. Attendance of fire appliances and equipment was in fact in excess of requirements, primarily because the Cheshire Fire Brigade and the Manchester Fire Control each assumed that the incident was in its own area. All necessary equipment was provided except that heavy calibre mechanical rescue equipment was not readily available in the quantity called for in such a case. It was not suggested that this deficiency had any serious results in this case. The total number of rescue workers and technical personnel who

attended was about three hundred and it was estimated that about an equal number of civilians were intent on rendering help in every possible way. Unfortunately, these public-spirited willing workers tended to hamper rather than assist the operation. There was no single control over the various services. The rapid mobilisation of so many vehicles inevitably caused traffic congestion. Such conditions are not surprising, following a terrible accident of this kind. The way in which the operation was carried out redounds to the credit of all concerned and there was no way in which any lives could have been saved or the material damage reduced.

TECHNICAL INVESTIGATIONS AND DESCRIPTIONS

A Senior Inspector of the Accidents Investigation Branch of the Ministry arrived at Ringway about $2\frac{1}{4}$ hours after the accident. He saw Mr. Pettigrew the same evening and, having heard what he had to say about the starboard flaps, had a search made during the night among the rubble, and by the following morning had recovered most of the starboard flaps and also recovered No. 2 starboard flap unit and its fittings. These were sent to Farnborough by air for examination at the Royal Aircraft Establishment. Later the whole of the wreckage was sent to Farnborough and, as far as possible, assembled there.

In order to make this part of the report as clear as possible to the non-technical reader, I will give a brief description of the flaps, flap units and ailerons. At the rear trailing edge of each wing there are three flaps numbered 1 to 3 from inboard to outboard. Except when taking-off or landing the flaps are within a kind of housing formed by the upper and lower falsework structures which are fixed to the trailing edge member of the wing, and are a continuation of its upper and lower surfaces. There is a quite elaborate mechanism, involving a chain drive and a telescopic arm, by which the flaps can be lowered, i.e,. made to move outwards towards the rear of the aircraft and downwards. There are five positions for the flaps: up; 20°; 32°; 40°; and 47° (down). The flaps on both wings all move together, being operated by a single control, and the effect of lowering them is that the pressure upon them of the air as the aircraft goes forward has a retarding and lifting action. Each flap consists of two separate parts, a main flap and a fore flap. There is a slot between the fore flap and the upper false work and another between the fore flap and the main flap. The slots remain open when the flaps are lowered and closure of either of the slots would substantially lessen the effectiveness of the flap. After the accident the flaps were found to be in the 32° position, which would be normal for the stage reached by the pilot immediately before the banked turn occurred.

The three flaps on each wing are supported by four structures called flap units which are attached to the trailing edge of the wing and protrude towards the rear within the falsework. No. 1 flap unit supports the inboard edge of No. 1; No. 2 flap unit, the outboard edge of flap No. 1 and the inboard edge of flap No. 2; No. 3 flap unit, the outboard edge of flap No. 2 and the inboard edge of flap No. 3; and No. 4 flap unit, the outboard edge of flap No. 3.

There is an aileron (consisting of two parts, inner and outer) on each wing, situated at the trailing edge of the wing and outboard of the flaps. The ailerons are hinged to the trailing edge and are controlled by a single control in such a way that when the starboard aileron moves up the port aileron moves down and vice-versa. The effect of moving the starboard aileron down is to tend to raise the starboard wing and so to make a banked turn to port, or to overcome any tendency to make such a turn to starboard.

In order to prevent damage to the ailerons when the aircraft is on the ground, they can be locked in the neutral position by a control lever in the cockpit. The same control lever operates to lock all the control surfaces (i.e., rudder, elevators, and ailerons) simultaneously. This lever should of course, never be operated in flight. It could not be operated accidently because it requires a considerable pull to move it. No experienced and competent pilot would ever think of locking his control surfaces while approaching to land, if he did so, his aircraft would be completely uncontrollable. When the lever is moved to lock the controls it pulls a wire which pulls seven separate wires, each of which operates one lock, there being two locks on each aileron and one lock each on the elevators and the rudder. The manner of locking is that a movable arm becomes engaged between jaws fixed to the control surface. Although no particular clearance between the arm in its disengaged position and the jaws had been specified generally, B.E.A. had required that this clearance should be at least 0.1 inch. In practice it was usually more.

Each flap unit is attached to the trailing edge member of the wing in this way (see figs 1 and 2). To the top and bottom of the trailing edge member are bolted fittings; (these are called "forward fittings"). To the top and bottom of the front edge of the flap unit are bolted fittings; (these are called "aft fittings"). The fittings are of aluminium alloy. A bolt passes from aft forward through the top aft fitting, the trailing edge member, and the top forward fitting, and is secured by a nut. On flap units 1, 3 and 4 a bolt passes from aft forward through the bottom aft fitting, the trailing edge member, and the bottom forward fitting, and is secured by a nut. On No. 2 flap unit the bottom aft fitting has a small lug and there is one bolt passing through the main part of the aft fitting, the trailing edge member and a forward fitting, and a smaller bolt passing through the lug, the trailing edge member and a subsidiary forward fitting. (The reason for the subsidiary bolt is that the position of No. 2 flap unit in relation to the wing rib was such that the main bolt could not be placed centrally in the fitting). In every case the bolt is secured by a nut at its forward end. The bolts in different positions are of different sizes. They are of high tensile steel as also are the nuts.

From the point of view of this report the important flap unit is starboard flap unit No. 2. The important fitting is the aft lower fitting of that unit (see figure 3) and the important bolt is the larger bolt through that fitting. This was a 9/16 inch diameter bolt and the smaller bolt at the same fitting was 5/16 inch. In the wreckage were found the flap unit and the main part of the aft bottom fitting with the head and part of the shank of the 9/16 inch bolt (broken off so as to leave only one thread), while the lug of the fitting was still attached to the trailing edge member by the 5/16 inch bolt. The remainder of the 9/16 inch bolt together with its nut was never found, despite diligent search. The surface of the break in the 9/16 inch bolt showed on examination an appearance which left no doubt in the mind of an expert (and my Assessor Prof. Redshaw is quite satisfied about this), that the bolt had been subject to fatigue: about 20 per cent of the area appeared to have had a fatigue crack spreading slowly across it, about another 70 per cent showed a more rapid progress of fatigue, and the final 10 per cent had suffered a sudden tension fracture. The break of the lug from the remainder of the fitting cannot be described with particularity because fire had so affected the broken surfaces as to destroy evidence of the metallurgical character of the fracture. When found, the flap unit was completely detached from the wing but the indications were that the top fitting had broken after the lower part of the unit had been detached from the wing and it seems probable that the top fitting broke only in the course of the final break-up of the aircraft.

At this point it is possible to draw prima facie conclusions as to how this accident may have happened. The 9/16 inch bolt was badly fatigued and the ultimate breaking of it may have been the first step in the chain of causation leading immediately to the accident. If it did break the stress on the lug and the 5/16 inch bolt holding it would be considerable, and it was the lug that broke. Alternatively the lug may for some reason have broken first and the stress so imposed on the 9/16 inch bolt would then have been more than in its fatigued condition it could bear. In one or other of these ways the lower part of the flap unit became detached from the wing. The air pressure on the lower-

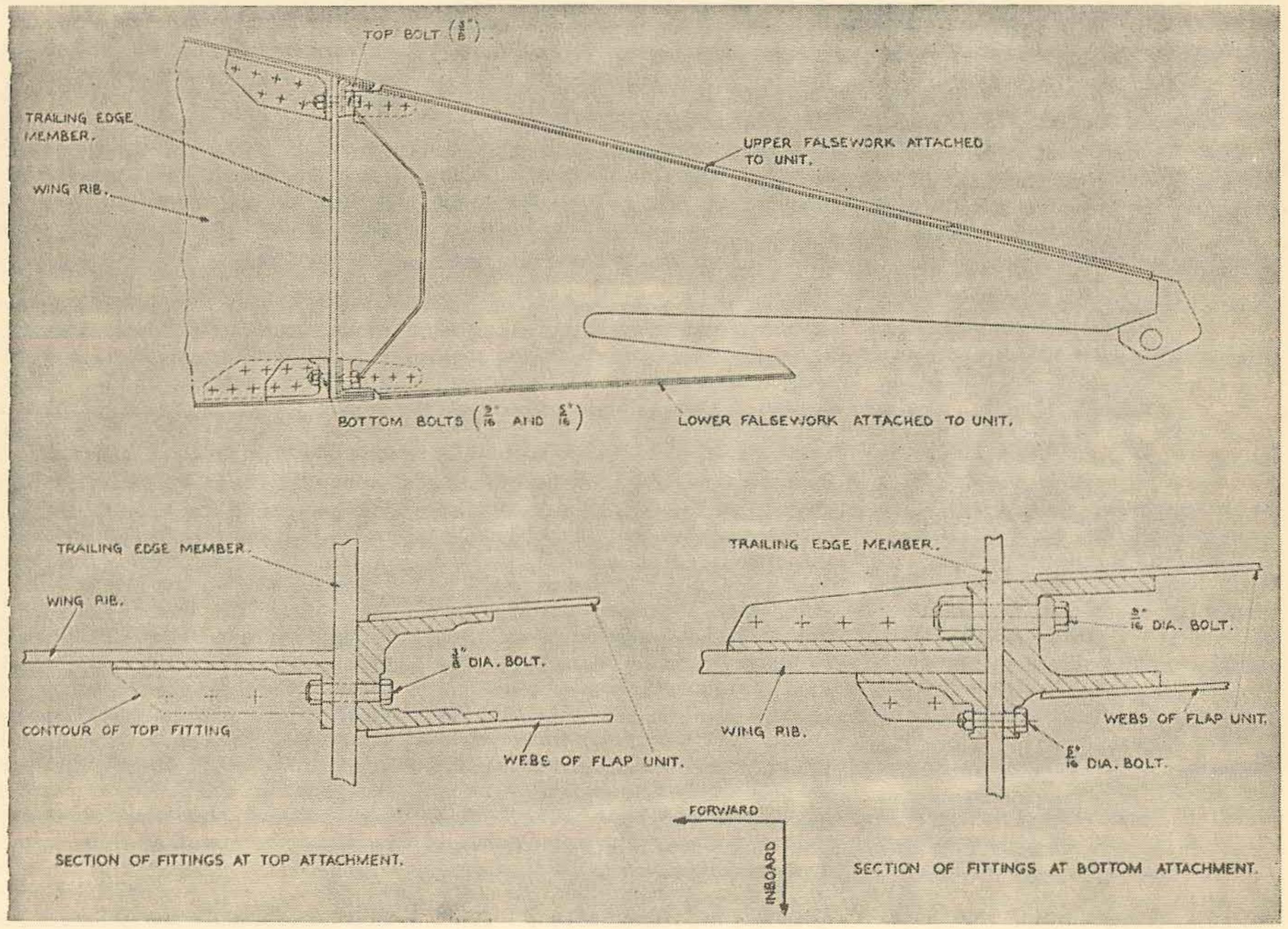


Fig. 1

ed flaps caused them to lift the No. 2 unit so that it pivoted about its top fitting. Matters now to be considered are: is there any ascertainable cause of the fatigue in the 9/16 inch bolt? Was there any reason (unless the bolt broke first) why the lug should break? Were the ailerons put out of action in any way?

Fatigue in a piece of metal is caused by numerous alternations of stress in it. It is most liable to occur at a place of high stress concentration such as a sharp re-entrant corner, e.g., the bottom of a thread in a bolt. All the main bolts supporting flap units were subject to certain alternations of stress but it had not been supposed up to the time of this accident that stresses of sufficient magnitude could occur a sufficient number of times to bring about fatigue within the period in which this happened to this particular bolt. The question arose—might such fatigue be of wide occurrence in main bolts supporting the lower fittings of flap units in Viscount aircraft?

To obtain an answer to this question an examination was undertaken by R.A.E. of most of the bolts from lower fittings of flap units in 100 Viscounts (out of 189 then operating). This involved the examination of 845 bolts. As a result it was found that:

(a) in W.E. four bolts besides the one which had been broken showed signs of fatigue — the fatigue being substantial in the 9/16 inch bolt from the lower fitting of the No. 2 port flap unit and slight in the other three bolts (No. 2 starboard 5/16 inch; No. 3 starboard; No. 2 port 5/16 inch);

(b) including those from W.E. a total of 33 bolts showed signs of fatigue. This was considered a significant proportion but it is right to say that none of the bolts, except the two in W.E. that had substantial fatigue, were more than slightly affected, the largest of the other cracks not being more than two per cent of the area of cross-section of the bolt.

All the fatigued bolts came either from No. 2 or from No. 3 flap unit. No explanation of why these were affected whilst the bolts from Nos. 1 and 4 were free has been definitely established. The incidence in bolts from No. 3 was slightly greater than in those from No. 2 (6.7 per cent as against 5.4 per cent and 4.9 per cent); but see the end of the next paragraph. The incidence tended, as was to be expected, to be greater in aircraft which had had more landings. (Where a bolt had been changed the relevant number of landings was of course the number since the new bolt was put in). Among the No. 2 bolts a striking difference was apparent between aircraft which had been modified in a certain way in certain conditions, and those which had had the modification introduced in other conditions. It is necessary to explain this modification known as Mod. 799, in some detail. It was applied to W.E. in March, 1955, since when W.E. had flown 3,639 hours and had made 2,973 landings.

According to the original design the larger bolt for the lower fitting of No. 2 flap unit was a 1/2 inch bolt. Now with the earlier Viscounts some trouble was experienced with the flaps. The defects were not of a serious nature. They were such minor defects as are usually experienced with a new type of aircraft. W.E. itself had some of these flap troubles but not to an exceptional extent and there is no reason to suppose that any extra stresses on the supports of the flap units were caused by them. However, one thing that happened in a number of Viscounts was that the chain broke in the No. 2 flap unit and it was decided to strengthen this chain. For valid technical reasons it was considered that the chain ought to be the weakest part of the unit (because a break in the chain was less likely to have serious results than a break in the structure), and so when the chain was strengthened it was decided to strengthen various parts of the unit, including the main bolt holding the lower fitting. After calculations as exact as the nature of the problem permitted, the decision was to increase the diameter of the bolt to 9/16 inch. The calculation involved assessing the load expected to be carried by the bolt, and applying a factor of 1.5 to arrive at the "fully factored load" and then applying another factor to give a further reserve of strength; for flap attachment bolts in Viscounts this second factor was at least 1.6 but for this particular bolt it was about 2.4, that is to say the fully factored load was about 6 tons and the strength of the bolt was sufficient for a static load of about 14 tons. The name of Mod. 799 was given to the whole modification including the provision of a stronger chain and a larger bolt with the associated work. In Viscounts which were in course of manufacture and which had not yet reached the stage at which this part was completed, the modification was introduced before assembly; when the examination was made after the accident none of these bolts were found to be fatigued. In Viscounts which were in the course of manufacture but had had this part completed, the modification was made in the factory; one of these bolts was fatigued out of 35 examined. In Viscounts which were already in operation (which included W.E.) the modification was made elsewhere than in the original factory; 10 of these bolts were fatigued out of 52 examined. It seems clear the modification after delivery tended to increase the incidence of fatigue in No. 2 bolts. This modification cannot, however, be regarded as the cause of all the fatigue found since the No. 3 bolts had not been modified at all and yet had a significant incidence of fatigue. (Comparison of the actual percentage incidence between No. 2 and No. 3 cannot usefully be made since the No. 3 bolts were on the average a considerably older population.)

Of all the Viscounts to which Mod. 799 was applied after delivery to operators, one was modified by Vickers, four by Aer Lingus and seventeen (including W.E.) by Marshalls Flying School Ltd., of Cambridge. This last mentioned company, despite its name, carries on an extensive business in work in connection with the repair and modification of aircraft and has a high reputation in that connection. While five fatigued bolts were found in the

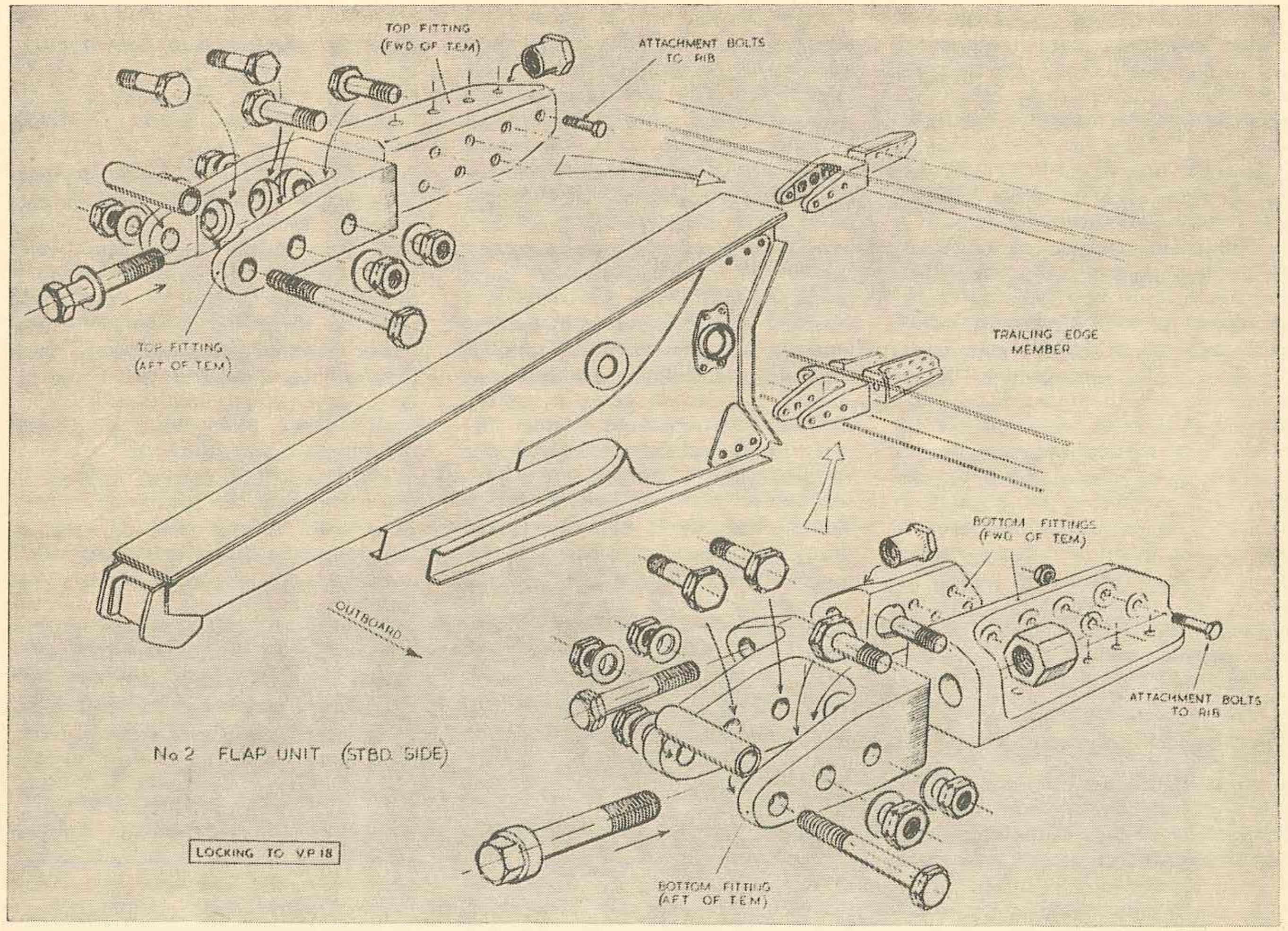


Fig. 2

17 aircraft modified by Marshalls, one was found in the aircraft modified by Vickers and four (two in one aircraft and one each in two others) in those modified by Aer Lingus.

Examination of the fitting concerned on W.E. after the accident revealed certain unusual features as follows:—

(a) the marks of the bolt heads and nuts (both the original 1/2 inch one and the later 9/16 inch one) on the fittings were uneven, i.e., were more pronounced at one side than the other, indicating that either the bolt or the hole was out of true; and consequently the loading on the bolt would not have been truly axial; the position of the deepest impression of the nut of the 9/16 inch bolt corresponded approximately to the fatigue origin on the bolt; (something similar, and even more pronounced, was found in the corresponding position on the port wing and, on the assumption that in each case the shaft of the 1/2 inch bolt was true to its head, it appeared in each case that the 9/16 inch hole was not concentric with the 1/2 inch hole and that the axes of the original and the new hole were not parallel);

(b) the front face of the fitting had been milled down by about 0.1 inch—one effect of this being that the lug was 0.1 inch thinner than as designed;

(c) because the part of the trailing edge member of the wing against which the fitting had to rest had three snap rivet heads projecting from it three small depressions had been made in the face of the fitting (see fig. 3); but the edge of two of these depressions had fouled their rivet heads so that the face of the fitting had not been lying true against the trailing edge member.

All these matters were closely investigated and the evidence about them is summarised in the following paragraphs.

The wings of W.E. (apart from the flaps) were manufactured by contractors, Saunders-Roe, a company of high reputation with long experience in the aircraft manufacturing industry. As to the parts relevant to this Inquiry, Saunders-Roe manufactured the trailing edge member, the forward fitting and the after fitting and reamed holes for the 1/2 inch bolt. The holes in the trailing edge member and the forward fittings were originally left at 7/16 inch and were reamed to 1/2 inch on final assembly. After delivery of the wing to Vickers, for some reason a replacement for the forward fitting was asked for by Vickers, and was delivered separately by Saunders-Roe. This replacement was delivered with a 7/16 inch hole which was reamed by Vickers to 1/2 inch. Because of the modification which later took place it is impossible to tell whether it was the 1/2 inch hole or its bolt which was out of true. It appears from the evidence that it is quite possible that in the course of the successive reamings some malalignment of the hole came about. However, for the purposes of this report any malalignment of the 1/2 inch hole is irrelevant unless it led to the malalignment of the 9/16 inch hole.

Modification 799 as already explained was performed on W.E. by Marshalls. They reamed a 9/16 inch hole which may not have been coaxial with the original 1/2 inch hole. The reaming of this hole on an assembled wing was an awkward job. Vickers provided three reamers graded in size and Marshalls supplied a socket to fit over the head of the reamer and a series of extensions to bring the operating point clear of the flap unit. The reamer was operated by a ratchet attached to the outermost extension. This extension was supported by passing it through a hole in a steadying pad. The mechanic operating the ratchet would be unable to see the reamer. When the hole had in this way been enlarged to 9/16 inch it was cleared of swarf and checked with a dummy bolt and then a 9/16 inch bolt coated with a jointing compound was inserted. Owing to the obstruction of other parts of the structure the means of tightening the nut on the bolt was unusual: one man inside a tank compartment in the wing had to fit the nut on to the bolt and hold it with a spanner, while another man turned the bolt head from outside. Tightness was checked by an Inspector and the nut was locked by popping. (At that time there was no requirement for torque loading; since the accident a requirement has been introduced for the tightness of such bolts to be checked by a torque loading figure of 350 lb. ins. However, it does not appear that the tightness of the nut was a critical factor in relation to the development of fatigue.)

Subsequent experiments go to show that when a hole is enlarged in the way described the original hole normally tends to keep the reamer in true alignment. Nevertheless in the result the axis of the 9/16 inch hole was not true. How this came about remains uncertain. At the time when W.E. was modified Marshalls had already applied Mod. 799 to about ten Viscounts. Before any of this work was done Marshalls' inspectors and operatives concerned spent some time at Vickers' factory to study the operation; moreover when the first three or four modifications were done by Marshalls an inspector from Vickers was present. It appears that at the time when this work was done people highly experienced in this type of work would never have supposed that a reamer carefully operated in the manner described would "wander" appreciably. I am satisfied that inspection on W.E. was carried out as fully as was practicable by Marshalls' inspector: the design of the fittings made it impossible to examine the seating of the nut and only about 40 per cent of the seating of the head could be seen and that not accurately. The jointing compound squeezes out and makes it still more difficult to observe the seating. It was suggested on behalf of the British Airline Pilots' Association that Marshalls' records were not as full as they should have been. The records showed the work done, the inspector and the gang of men responsible. In my opinion it would be unreasonable to ask for more. To record the exact part played by each operative in doing a job would involve an amount of clerical work that would not be justified.

The machining of the face of the aft fitting was done in Vickers' workshops. There should have been a concession note for this work but

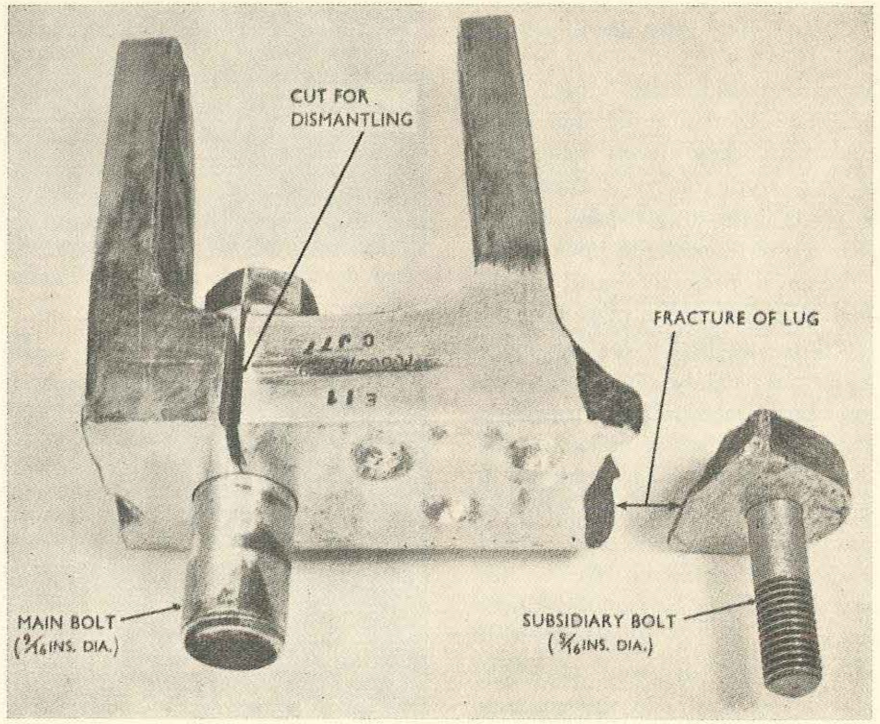


Fig. 3

it has not been possible to find one and probably none was issued. I was assured, and accept the assurance, that the work would not have been done without obtaining the oral consent of the design department and that those responsible for the design believed and still believe that the fitting was still of adequate strength with this amount of metal removed. (A similar fitting on the prototype 700 was treated in the same way and on that occasion a calculation was made to ensure that the strength was not reduced too much and a note was made that a concession had been granted.) The reason for the alteration was probably that on assembly the flaps were found to be very slightly out of alignment and that the machining was done to get them properly aligned. The only possible materiality of the matter is that the lug might not have broken if it had been of the original thickness.

It was by an oversight in the original detailed drawings that snap-head rivets and not counter-sunk rivets were indicated. Only W.E. and one other aircraft had been fitted with these rivets when the error was discovered. Thereafter the rivets were counter-sunk but on W.E. it was considered unnecessary to remove perfectly good rivets which were already in place and the procedure adopted was to make depressions to accommodate the rivet heads (see fig. 4 top drawing). When the 0.1 inch of metal was removed the depressions remaining in the surface of the fitting would obviously be too small and would have to be enlarged. Again this work should have been covered by a concession note but apparently was not. However, it was obviously necessary to do it. For some reason which is unexplained, two of the depressions were not exactly in the right position and instead of completely enclosing their rivet heads the edge of these two rested on the edge of the rivet head. This meant that the forward face of the fitting was not in close contact with the trailing edge member. (Certain calculations suggest that the maximum distance between them was about 0.03 inch but this figure is not definitely established (see fig 4 lower drawing)). Two possible consequences would be (1) that when the two bolts were tightened up the fitting would be under stress which may have caused the lug to break off. (If this stress had directly caused such a fracture it would probably have happened at once, but it is possible that a minute crack was caused which led in time to some degree of corrosion followed eventually by fracture.) (2) that when the original 1/2 inch bolt was removed for Mod. 799 the fitting still held by the 5/16 inch bolt would slightly

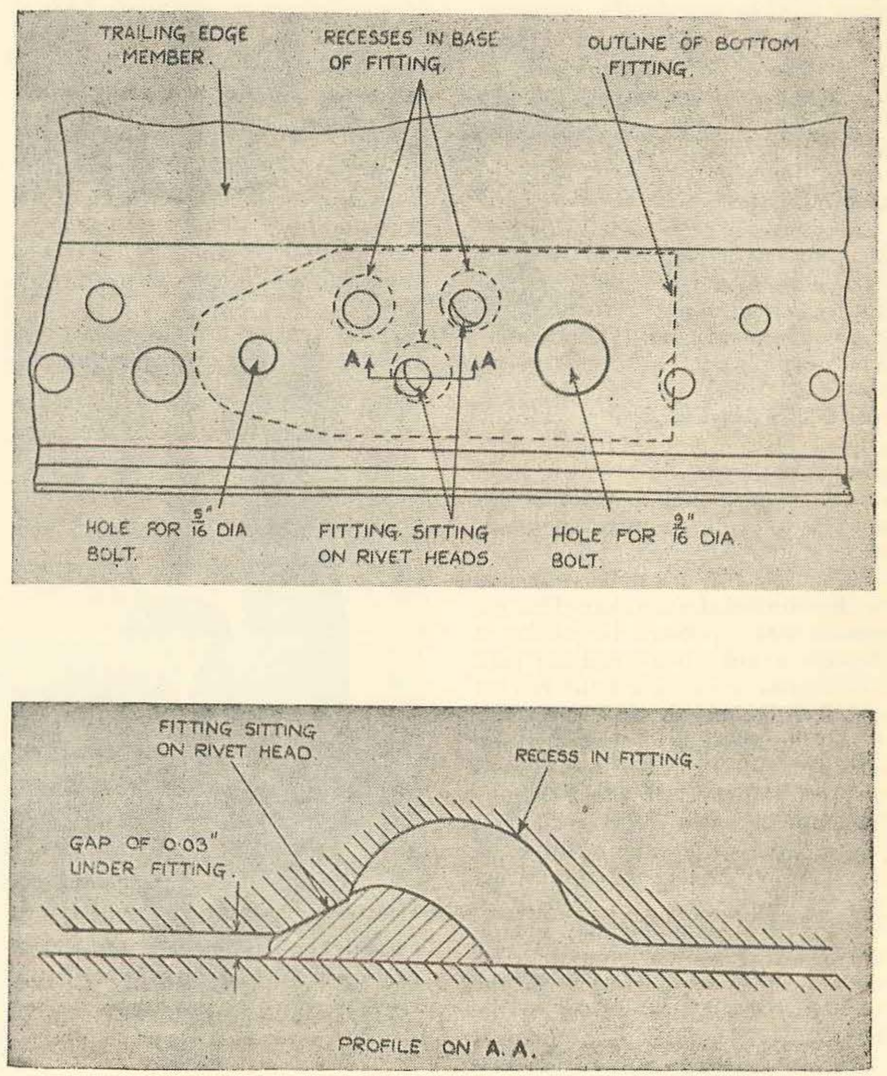


Fig. 4

spring away at the other end of its face (though the attachments of the fitting to the flap would tend to reduce any such springing) so that it would be in a slightly different position when the reaming operation was performed from the position it would take up when the 9/16 inch bolt was inserted and the nut tightened. This, therefore, is a possible cause or contributory cause of the faulty seating of that bolt. It must, however, be remembered that the seating of the corresponding bolt on the port wing was also faulty, although the fitting was there lying snugly against the trailing edge member.

A careful experimental investigation has been made by R.A.E. into the question of whether faulty seating of the bolt head or the nut had any effect on the incidence of fatigue. The results establish that an inclination of a few degrees may drastically reduce the fatigue life of the bolt. Unless the inclination was so small that the bolt head or nut could bed down on the fitting the effect on fatigue life was not related to the angle of inclination. Broadly speaking the investigation showed that a bolt accurately seated could withstand about twice the alternating load of a bolt with inclined seating. But the effect of inclined seating on fatigue life in certain ranges of alternating load was found to be of a high order. The findings may be summarised as follows: with loads up to four tons to the square inch both well-seated and badly-seated bolts still had an indefinitely long life; between four and eight tons to the square inch, well-seated bolts still had an indefinitely long life but badly-seated bolts had a limited life; from eight to twelve tons to the square inch both had a limited life but the life of a well-seated bolt, expressed in alternations of load, was about 50 times that of a badly-seated one. Up to the time of these investigations it was not known even to experienced aeronautical engineers that the seating of a bolt could have such an important bearing on fatigue life; the matter had apparently never been studied before except for one series of experiments in the United States, the results of which had been published in 1955 but were not widely known. It is now clear that the malalignment of both 9/16 inch bolts in W.E. is an important factor to be considered in relation to the high degree of fatigue which had developed in both of them. On the other hand it cannot be said that no fatigue would have occurred if the bolts had been accurately seated: for among the 28 bolts from other Viscounts found to be cracked were at least two which had cracks to the extent of about two per cent. of the cross-sectional area and which showed no signs of malalignment.

Other experiments were made by R.A.E. and Vickers to discover what deformation of the flaps would be likely to result from the failure of the connection at No. 2 unit bottom fitting and what effect on the flight of the aircraft this would have. The conclusions reached were that in all probability the top fitting held and the unit pivoted about this point until the bottom of it came away to a distance of about six inches from the trailing edge member. The distortion of the starboard flap system which resulted (involving the closing of the slot between the fore flap and the upper falsework) would introduce sufficient asymmetry to cause the roll and turn which was observed, provided no corrective action was taken by the use of the ailerons. The rolling tendency would, however, be well within the corrective power of the ailerons. This matter was investigated by both Vickers and R.A.E. Vickers made a mechanical test on a wing, simulating the conditions believed to have affected W.E. and obtained a certain deformation of the flaps. They then calculated the aileron angle necessary to hold the resulting roll and concluded that it was probably 2.4° or at most 3.8°. R.A.E. made flight tests and simulator tests and concluded that the deformation might have brought about a somewhat greater loss of lift than was found by Vickers and that to cause the roll described by witnesses flap damage equivalent to about 4° of aileron would be needed. Ailerons, if working normally, could turn through an angle many times as great as this. (Simulator tests, checked by full-scale flights showed that control by the use of rudder alone, with the ailerons locked, would have been marginal and almost certainly impossible in practice under the conditions existing at the time.) This leads to a consideration of whether the ailerons were locked in some way.

The wire controlling the locking devices of the starboard aileron passed through a fair-lead on No. 2 flap unit. Just inboard of the unit it passed in front of a fuel pipe (see fig. 5). Geometrically it is clear that a movement of the unit such as has been described above would tend to pull on the wire (the extent of this pull being much magnified by the proximity of the fuel pipe) and so to lock the aileron. This would cause the port aileron also to be immovable. Tests which were made indicate that while the degree of movement obviously depends on the exact position of the wire (which cannot be ascertained), it would have been possible for the ailerons to be locked in this way, assuming a position for the wire within 1/4 inch of the fuel pipe which, though unusual (as shown by examination of a number of other Viscounts), does occur in a small proportion of cases. There are several indications in the wreckage that the ailerons were in fact locked.

There was also some indication in the wreckage that the elevators were locked or partially locked and the rudder was locked. These could not have been locked by any such means as are described in the preceding paragraph. It appears that the control lever which operated all the locks was not at the time of the impact in the off position but was at least a quarter of the way towards the lock position. That would probably be sufficient just to cause the locks to begin to engage. This leads to the question—did the pilot operate the locking lever and if so, why? The most probable answer, supported by the views of competent witnesses and confirmed by the advice of my Assessors, is this: the movement of the flap unit locked the ailerons; the pilot, when the roll began, at once tried to move his ailerons and found that they were locked, in desperation he (or the co-pilot on his instructions) seized the locking lever to see if he could free the ailerons and (it being at that time in the unlocked position) pulled it towards the locked position. This probably happened at a time when the aircraft was in fact, irretrievably out of control. The locks would not necessarily engage immediately but would do so on any control surface which reached the neutral position while the lever was being pulled. An alternative possibility is that in the break-up of the aircraft something caught the main locking wire and pulled it; but no evidence of this having happened could be found in the wreckage.

The question arises of whether B.E.A. could have discovered before the accident that bolts in W.E. and in some other Viscounts were affected by fatigue. None of the ordinary checks would have revealed this because such checks do not involve the extraction of such bolts. In about 1955 B.E.A. decided to apply to Viscounts a "10 per cent sampling check" system which had been worked out in co-operation with A.R.B. and the manufacturers for another type of aircraft. This check was to be carried out on the first Viscount in the fleet to reach 6,000 hours flying, then on the first to reach 12,000 hours and so on. At any one check 10 per cent of the aircraft's bolts falling within certain descriptions were to be removed for the purpose of inspecting the holes for corrosion. (The check was never intended as a safeguard against fatigue of bolts. Examination of such a small proportion of bolts at such long intervals would be of little use for that purpose.) From time to time additional items were added to the list. In August, 1956, bolts attaching flap units to the trailing edge member were added. Before the accident the first of the B.E.A. Viscounts to reach 6,000 hours (which was not W.E. but O.G.) had been subjected to this 10 per cent sampling check. This was on the 14th November, 1956. One of the bolts removed happened to be the 9/16 inch bolt from one of the No. 2 flap units. Although the check was primarily a check of holes and not bolts, bolts were examined by a magna-flux test and in other ways and then sent to the manufacturers for further examination. No cracks were then found in any of these bolts. At a later date after the accident the 9/16 inch bolt from O.G. was submitted to a very stringent examination and was found to have a minute crack.

TECHNICAL DISCUSSION

This section deals with a number of technical matters relating to the material, construction and assembly of the bolt and fitting which failed, to the forces involved and the probable causes of the fractures. The opinions expressed are those of my Assessors Prof. Thom and Prof. Redshaw which I fully accept.

The fitting was machined from a high strength aluminium alloy extrusion to specification D.T.D.363, the grain of the material running fore and aft. This was considered by the designer, and quite correctly, as being the most advantageous direction for the grain, but as a result the direction of the grain for the projecting lug provided for the 5/16 inch bolt was in an unfavourable direction; nevertheless, the thickness of the lug as designed, and its method of attachment, would not have caused any undue anxiety on this score. We know that the thickness of the lug had been reduced from 0.4 inch to 0.3 inch and that the fitting was assembled with its face clear of the trailing edge member; it would therefore have been scarcely surprising if the lug had been cracked by the tightening up of the bolts either initally or subsequently during the incorporation of Mod. 799. The elongation of aluminium alloy D.T.D.363 in the transverse grain direction would not be more than 2-3 per cent, and therefore it is reasonable to assume that after assembly, as far as stress was concerned, this lug was in a critical condition and it may well be that a small tension crack had already started in the very sharp corner of the spot face. A visual examination of the lug fracture showed that the failure was in bending with some shear and that the failure commenced at the sharp corner of the spot face. (As may be seen in fig. 3 the corner between the lug face and the main part of the fitting is rounded; the spot face impinged on the curved portion of the surface, causing a sharp re-entrant corner there.) As the fitting had been softened by fire, it would not be possible to say whether the failure of the lug was caused by fatigue, by stress corrosion, or by any other cause.

Both the 9/16 inch and 5/16 inch diameter bolts were manufactured from high tensile steel, to specification S.99, which calls for an ultimate strength of not less than 80 tons/inch^2; the limits on the bolts, and the holes through which they passed, conform to good engineering

practice. The bolts were threaded to B.E.S.A. limits and the threads were run out to mitigate the effects of stress concentration. Finally, the bolts were given the standard cadmium coating protection.

In addition to the evidence of fatigue cracks, fretting was observed on the shanks of various bolts including the 9/16 inch bolt under discussion. In this connection it is to be noted that it is very unlikely that any of these bolts were ever tightened sufficiently to prevent movement of the bolt in its hole. In the case of Whisky Echo this effect might have been augmented by a definite slackening of the bolts caused by creep deformation of the heavily-loaded rivet heads under the fitting. These combined probably explain the fretting marks. Fretting is, however, only in the very early stages and is not indicative of any appreciable movement along the axis of the bolt (since the edges of the marks are fairly sharp and correspond with the three thicknesses of metal which the bolt passed through). The fretting could not be considered as contributing to the failure of the bolt but it does indicate a degree of movement at this point which is relevant to the question of whether a bolt in tension should be used in such a situation.

It is necessary to consider the forces which would be operating on the bolt and fitting. As the flap unit is rigidly bolted to the wing trailing edge member, the reactions at the attachment are statically indeterminate. We have at the lower attachment a tension, an indeterminate shear force and an indeterminate moment. The exact values of these quantities depend on the elasticity and deformation of the structure, and are almost impossible to calculate. Considering the bottom attachment, as the loads on the flap unit with the flap in operation are predominantly upwards, the two attachment bolts would be subjected to a tension, an upward indeterminate shear force, and the indeterminate moment which would be transmitted to the structure as an additional tension in the bolt and a pressure on the trailing edge member from the edge of the fitting.

It is necessary to explain how the bolt could have been subjected to oscillatory stresses of such magnitude as to produce a fatigue failure. The

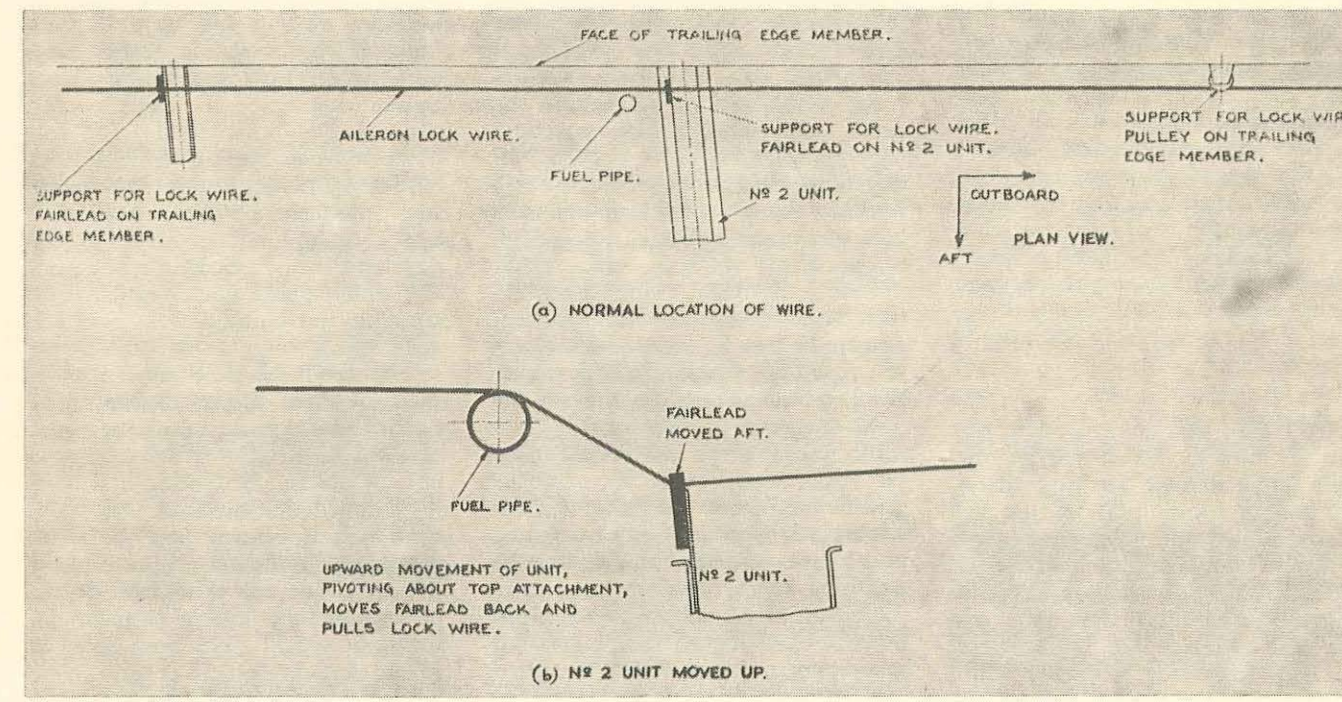


Fig. 5

bolt would be stressed due to tightening when initially assembled and it would be subjected to direct and shear stresses caused by the transmission of loads from the flap. Vickers made careful calculations at the time when Mod. 799 was introduced and these are substantially correct. The question of indeterminancy nevertheless remains, and as mentioned previously it is impossible to include everything. At some points in the calculation estimates of loads have to be made, and it is here that uncertainties are introduced. It is, however, to be noted that these calculations are for the design case, that is the worst case which the aeroplane is ever expected to encounter. Since the accident Vickers have made a series of flight load measurements on the Viscount flap support structures. These showed that the overall loads were in good agreement with calculated values. The conclusion was reached that high frequency oscillating loads occurring when the undercarriage was extended were unlikely by themselves to be critical from the fatigue point of view.

No. 2 flap unit is situated to the rear of the rib which carries the main undercarriage leg and therefore shocks transmitted by the leg on touchdown and subsequent taxying would cause oscillatory stresses in the bolt itself. Furthermore, the unit is in the proximity of the inner engine and therefore any buffeting of the flap from the propeller slipstream, and indeed from the undercarriage leg when in the down position, would cause additional oscillatory stresses on the bolt and fitting. The measured value of these oscillatory stresses was ± three tons/inch^2, or possibly 20 per cent greater. It is possible that during the life of the bolt there might have been a million such stress repetitions. Reference to a graph which summarised the results of experiments made by R.A.E. with a number of bolts shows that this is perilously near the failing load for bolts whose heads and nuts are not properly seated. It should be noted that No. 2 fitting is almost directly behind the inner starboard engine. There is little evidence as to the magnitude of the disturbances which might be thus produced. In this connection, it is to be noted that no fatigued bolts were found in numbers 1 and 4 flap units (which are not in the vicinity of the engines) in any of the aircraft which were examined.

Apart from the high frequency oscillatory loads it is necessary to remember the much greater alternating loads occurring in certain conditions on landing and at take-off. These, as appears from flight tests and from Vickers' original calculations for Mod. 799, were of the order of ± 11 tons to the square inch.

As the bolt was in tension the stress concentration factor could vary considerably from bolt to bolt depending as it does on the surface finish at the root of the thread. The bolt was manufactured from a high tensile steel which is very notch-sensitive, its Izod value being 25 feet lb. as compared with, for example, 40 feet lb. for a much lower strength high tensile steel of specification S.96. Therefore the surface finish of any portion of the bolt subjected to stress was of the highest importance. From the evidence given, we know that the threads were cut but not ground or polished and it was stated that grinding or polishing might possibly have done more harm than good which is probably quite correct. The point is that a very notch-sensitive steel was used and it was subjected to a concentration of stress which is inevitably associated with a threaded bolt under tension. It could be argued that the R.A.E. tests took account of the fact that the bolt was improperly seated, as indeed they did, but these tests were made under ideal laboratory conditions which might quite well be more favourable than the actual conditions obtaining on the assembled fitting. It is necessary to have in mind here the unknown applied moment and shear forces which almost certainly vary from aircraft to aircraft.

Having regard to all the matters referred to in the last three paragraphs, it is possible to account for the occurrence of such alternating loads as would, taken together, be sufficient to cause fatigue in the bolt in question and other bolts in similar situations supporting flap units in Viscounts.

During the Hearing, frequent reference was made to the advisability of using bolts in tension and it was stated that this was general engineering practice, and that a multiplicity of bolts in tension would not necessarily provide an additional safeguard. This is true, but it must be remembered that the bolt in question and its nut were of very high tensile steel. In most cases tension bolts are made from a low tensile ductile steel which would allow some imperfection in bolt head and nut seating to be accommodated; in addition, a low tensile steel would not be so notch-sensitive and therefore not so liable to the development of a fatigue crack from any small surface imperfection. The stress at the bottom of a thread is very much larger than the mean stress across the section, larger by the so-called 'stress concentration factor' which could be of the order of 3 or 4. If, instead of using the bolt in tension, the fitting had been so designed that the load was taken by a bolt in shear, then the stress conditions would have been entirely different. For one thing, the degree of redundancy in the attachment reactions would have been reduced as no fixing moment would have been present, but of more importance would be the fact that the threaded portion of the bolt would not have been subjected to stress and therefore it would never have been in danger of fatigue at this point.

As to the consequence of failure, it is clear that a fatigue crack in the bolt must have been present before the lug failed. If we assume that the fatigue of the bolt had reached such a stage that it finally failed in tension, then the failure of the lug must have been almost immediate. The loading conditions on the lug would be those of bend, shear and torsion but an examination of the fracture shows that the failure was in bending with some shear and that it commenced at the sharp corner of the spot face, a type of failure hardly consistent with the assumption of the prior failure of the bolt. The kind of failure which would occur if the 9/16 inch bolt failed first is shown in a photograph produced at the Hearing of a fitting deliberately broken as a test. This is quite different from the failure on W.E. and so gives support to the theory that the lug failed first. In all probability however it failed very shortly before the accident. If the 9/16 inch bolt in its severely fatigued condition had been bearing the whole load at this point it would probably have failed before the flaps reached the 32° position.

It is conceivable that the fatigue crack in the bolt had progressed only to 20 per cent of the area of its cross-section before the already over-stressed lug failed due to the operation of the flaps, or the lug may possibly have failed due to stress corrosion or fatigue at this stage. The surface of the fatigue crack in the bolt, after the well-defined initial stage, is such as to indicate a more rapid advance of the crack and it is just possible that this next stage could have taken place during the portion of the flight with the flaps retracted, when the loads would be small but of an oscillatory nature. The operation of the flaps prior to landing could then cause the final failure of the bolt.

Although it may well be that the lug failed first, nevertheless the failure of the fatigued bolt was inevitable. Even if the lug had remained intact the bolt would have failed before long, though its failure might have been preceded by the failure of the bolt on the port wing.

STEPS FOLLOWING THE ACCIDENT

Immediately after the accident, information of it was sent to Vickers, the Chief Inspector of Accidents, R.A.E. and A.R.B. Discussion on the causes of the accident and of precautionary measures to be taken at once began between all these and B.E.A. The measures that were taken were the result of agreement reached day by day as the investigations developed.

On the 14th March, Vickers sent telegrams to all licensed operators of Viscounts informing them of the accident. On the 15th March the broken bolt was identified and on the evening of that day it was sent to Vickers and by them to R.A.E. On the 16th March the conclusion was reached that the breaking of this bolt had something to do with the cause of the accident. On the 16th and 17th March the corresponding bolts on all Viscounts in the B.E.A. fleet were checked for tightness where they were except for two aircraft which, for special reasons, were flown home (one from Amsterdam to London Airport and one from Glasgow to Wisley) without passengers and without the use of flaps on landing. At a meeting late in the evening of 17th March it was decided that certain precautions should be taken, especially with regard to Viscounts which had exceeded 1,500 landings. At that time particular attention was being paid to checking bolts for tightness and instructions about this, dated 17th March, were issued by Vickers to all operators; aircraft which had not exceeded 1,500 landings were merely to have bolts tightened but aircraft which had exceeded 1,500 landings were to have bolts replaced if found to be loose, or in any case within a further hundred landings. There was at that time no instruction for immediate return to base or for special precaution in the use of flaps. On 18th March, Vickers sent fresh instructions to all operators, to the following effect: (1) on aircraft which have not yet reached 1,500 landings all bolts from bottom fittings of flap units should be inspected for tightness at the next check nearest to 100 flying hours; loose bolts to be tightened and relocked; (2) on aircraft which had exceeded 1,500 but not exceeded 2,500 landings not more than 20° of flap should be used and aircraft should return to base for immediate replacement of bolts at flaps units 2 and 3; (3) aircraft with over 2,500 landings should immediately return to base using not more than 20° of flap and fit new bolts on all four units.

B.E.A. followed these instructions. Viscounts which had exceeded 1,500 landings were brought home empty and without the use of flaps; in fact, all their Viscounts were brought in rather ahead of schedule and had all the bolts from bottom fittings of flap units changed. This was completed by 29th March.

On 19th March, Vickers sent to Viscount operators a request for return of bolts with instructions for identification. It may be mentioned that no cracks were found in bolts from any aircraft which had had less than 1,500 landings but a small crack was found in a 9/16 inch bolt from an aircraft which had had only 1,462 landings since Mod. 799. On the 22nd March, Vickers began drawings for a modification to strengthen the support of all the flap units (Mod. D2175). On 23rd March, Vickers sent to Viscount operators directions for the inspection of fittings (because although there was no evidence of fatigue in the fittings, it was known that the lug had fractured from a fitting in W.E.). By 27th March the first sets of parts for Mod. D2175 were ready and sets for this modification were sent out for all Viscounts by about 1st May. B.E.A. incorporated this modification in all their Viscounts between 8th April and 1st June.

Mod. D2175 may be briefly described as follows: The lower part of the flap unit had reinforcing gussets and angle plates added to it. A fishplate was added on the outside of the wing surface so that there is now an additional and redundant structure for carrying the loads.

These additional parts are designed to carry the full load as if the fittings and bolts were not there. In addition the designers worked to low stresses to ensure a good fatigue life. The fishplate reduces loads in the bolts to about half their original value. It is believed that this would extend the fatigue life of the bolts at least ten times. In addition, however, the bolts are to be examined periodically and replaced after specified periods. The examination is made in the laboratory and includes a development of the magna-flux test which development provides a very delicate test for small cracks. As a further safe guard the clearance of the locking lever has been increased so that even if the unit did become detached in the same way as on W.E. (which is considered to be practically impossible) the ailerons would not lock. Vickers have also introduced for themselves and their sub-contractors the practice of checking by a blueing test (which is a test for accurate seating) any bolts in any aircraft that take tension loads and any bolts in holes reamed out on assembly.

No criticism was made at the Hearing of the remedial measures adopted but it was suggested on behalf of the British Airline Pilots' Association that in addition it would be desirable that the aileron control cable should not pass through any guide on a flap unit, so that if this unit did become detached, there would be no possibility of the aileron becoming locked. I am satisfied that the modifications made as indicated in the last paragraph are sufficient for this purpose and there is no practical reason for altering the position of the fairlead. However, it appeared from the evidence that there would be no difficulty in having the fairlead on the main structure of the wing rather than on the flap unit, and it would be worth while to make the alteration if it would give pilots a sense of greater security.

Another submission made on behalf of the B.A.L.P.A. was that it would have been desirable to cancel all flights or at least all passenger flights of Viscounts immediately there was reason to believe that a structural fault had caused the accident, until a judgment could be formed as to where the fault lay and whether it was something peculiar to W.E. or not. Such a decision must always be a difficult one to make and I am not prepared to say that those responsible were in error in allowing flights to continue during the first few days of the investigations. It is accepted that from the 18th March onwards all necessary precautions were taken.

CONCLUSIONS AND RECOMMENDATIONS

I conclude that this accident happened because:—

(a) the lug broke;

(b) the 9/16 inch bolt broke because it was badly fatigued;

(c) the aileron became locked when the flap unit moved away from the trailing edge member.

I am satisfied that this was the probable order of events, though it is not certain that the lug broke before the bolt.

The breaking of the lug was probably an indirect result of the fitting having been machined down to the extent of 0.1 inch and of the fitting not having been seated close against the trailing edge member. It was unfortunate that the 0.1 inch of metal was removed. The faulty seating of the fitting was a serious defect of workmanship. This was not discovered on inspection and it may well be that because of the absence of a concession note for the work done on the fitting attention was not directed to checking the accuracy of the seating. All these matters concern Vickers alone and have nothing to do with Saunders-Roe or Marshalls.

The view I have formed about the severe fatigue of the 9/16 inch bolt is that it was the result of a number of factors. I think the magnitude and number of alterations of stress to be expected at the bottom attachment of Nos. 2 and 3 flap units were under estimated by the designers. This is the only way in which the significant incidence of fatigue in bolts from both these units can be accounted for. Secondly, I am satisfied that the method of effecting Mod. 799 after delivery made it impossible to do the work with as much precision as when the modification was made in the course of manufacture. This would explain the substantial incidence of fatigue in main bolts from bottom fittings from units so modified by each of three highly reputable organisations. Thirdly, I have no doubt that the larger number of landings performed by W.E. than by nearly all other Viscounts is one reason why there were bolts in it more severely cracked than in any of the others. Additional factors which may have operated in this connection are that as this was the first machine of its type, the manufacturing difficulties would be greater than for later models and (though this cannot affect the 9/16 inch bolts) that the use of this aircraft for specialised training of pilots may have involved some additional stress. Lastly, I am satisfied that the faulty seating of the head and nut of this particular bolt brought about the advanced state of fatigue that was present in it. Because the corresponding bolt on the port wing is also out of alignment I do not feel that the malalignment of the bolt in question can with any confidence be attributed to the faulty seating of the fitting. It is however possible that the fitting sprang slightly when the bolt was removed for enlarging the hole and that this led to the hole being reamed out of true. Whether this was so or not, it is fair to say that the state of knowledge of these matters at the time when the reaming was done was not such that those responsible could have been expected to know that a small error in the alignment could lead to a great acceleration of fatigue. If this had been realised the seating could have been submitted to a test known as a "blueing test" which would have disclosed the error; the normal practice did not require such a test. Whatever mistakes may have been made in connection with any of the matters discussed in this paragraph, I do not consider that any of them could properly be described as a wrongful act or default or negligence.

As to the locking of the ailerons, nobody could have been expected to foresee this and neither the placing of the control wire nor the provision of a fairlead attached to the unit, could in my opinion, be called a fault in design.

In coming to a final conclusion about the cause of this accident, I consider that the fatigue of the bolt was really the effective cause. It was this bolt that was designed to carry most of the load and, even if the lug broke first, there is nothing to show that a major structural failure would have occurred if the bolt had not been severely fatigued. It was, in fact, in such a condition that it was bound to break sooner or later, and if when it broke the lug was still attached by the smaller bolt to the trailing edge member the lug and the small bolt had imposed on them a load which (although according to the evidence they were both deemed strong enough to carry it) it was not their function to bear. The locking of the ailerons is to be regarded rather as something which made it impossible to prevent an accident than as something which caused it. In answering the formal questions, I consider it sufficient to specify the effective proximate cause of the accident.

The questions put to the Court were as follows:—

1. What was the cause of the accident?

2. Was the accident due to or contributed to by the act or default or negligence of any party or any person in the employ of that party?

The answers of the Court are as follows:—

1. The cause of the accident was the fracture of the 9/16 inch bolt holding the bottom of the No. 2 starboard flap unit. The fracture was due to fatigue.

2. No.

I have considered very carefully with my Assessors the question of whether recommendations for the future can usefully be made. Different opinions were expressed at the Hearing by highly qualified witnesses as to the general question of the use of bolts in tension for supporting important structures. No absolute rules can be laid down as applicable on all occasions and future practice must take account of future developments in knowledge and experience. I am, however, impressed with the difficulty of calculating the magnitude of the alternating stresses on such a bolt and how often they will occur, and I am satisfied that until this accident happened it was not realised that the precise alignment of such bolts might be of great importance. I have considered whether to recommend a periodical laboratory examination for fatigue but it appears that once there is any sign of fatigue its development may be so rapid that an effective system of checking would hardly be possible and would in any case impose an undue burden on operators. For that reason I consider that recommendations should be directed to the avoidance of fatigue rather than to detection and remedial action.

I therefore recommend:—

(a) that reliance on a single bolt in tension for the support of a primary structure should be avoided if possible;

(b) that where such bolts are used an ample margin of strength should be allowed (having regard to the material of which the bolt is made) so as to ensure that fatigue will not develop at any time in the life of the bolt;

(c) that where such bolts are used the seating of the bolt and nut should be carefully checked.

COMMENT

On 18th March, 4 days after the accident, a cable was received in Australia from the manufacturer recommending that aircraft with less than 1,500 landings should have the bolts concerned tested for tightness at the next check nearest 100 flying hours, also that aircraft with over 1,500 hours should be inspected on return to base and all loose bolts replaced. These recommendations were put into effect immediately, but as an extra precaution, the figure of 1,500 was reduced to 1,000. These checks revealed three loose bolts in high time aircraft.

A further cable from the manufacturer on 19th March, advised that aircraft with between 1,500 and 2,500 landings should be returned to base for immediate replacement of bolts at flap units Nos. 2 and 3. On such flights flap in excess of 20 degrees was not to be used. Aircraft with over 2,500 landings should be returned to base under the same conditions for replacement of ALL bolts. Following this advice and as a result of discussions with local operators, the Air Registration Board in England and the Department of Civil Aviation decided that all aircraft were to be grounded on return to base. This action was completed the following morning.

Before being fitted, all new bolts were subjected to magna-glow and ultra-sonic tests. Following release back into service of three aircraft with less than 1,000 landings, advice was received from England that a number of cracked bolts had been found in aircraft with as few as 2,400 landings. The three aircraft which had resumed service were then recalled and grounded.

Before being released for service all bolts were changed in each aircraft and a necessary modification incorporated. Since that date periodic inspections in accordance with the manufacturer's recommendations have been and will be carried out in future.

Helicopter Strikes Flag Pole, Farmingdale, New York

(Summary based on the report of the Civil Aeronautics Board, U.S.A.)

On 19th October, 1957, a Bell Helicopter struck a flagpole and crashed at Farmingdale, Long Island, New York. One of the two passengers was killed, the other passenger and the pilot were seriously injured, and the helicopter was demolished.

The Flight

The aircraft had been chartered to attend a public gathering where the helicopter was to land near the assemblage at a prearranged time and deplane a contest winner whose arrival was to feature the occasion.

The site for the landing was on the mall of the Long Island Agricultural and Technical Institute and had been chosen and approved by a company pilot. This approval, together with a sketch of the area showing a nearby flagpole, was passed on through company channels so that it was in the possession of the pilot at the time of the accident. The signal to land was to be an opened bed sheet spread on the ground by a company agent.

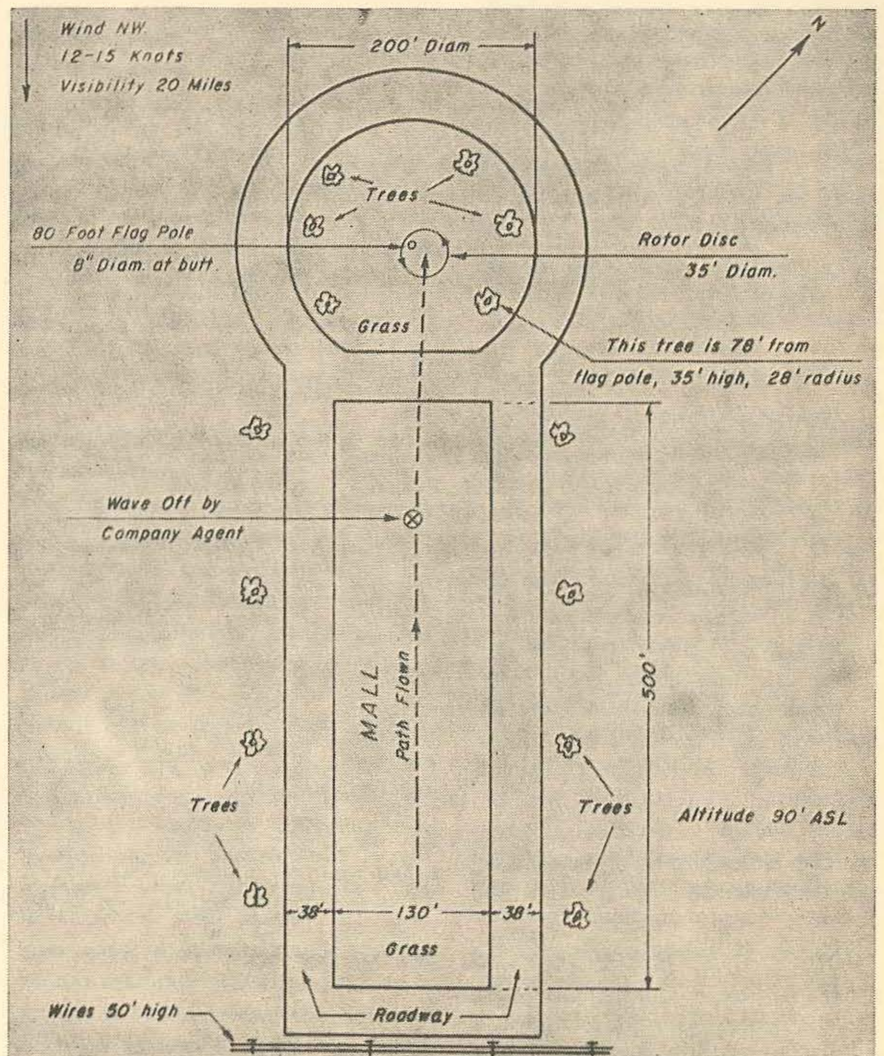
Departure was made at 1215 hours and the helicopter arrived over the campus area and circled to the left at an altitude of about 500 feet. During this time the pilot saw the folded bed sheet on the ground, presumed that it was the landing signal, and started his approach.

The descent approach into the mall was steep, over wires, and into the wind (see sketch). The ground agent on the mall had not received instructions to display the landing signal, so he waved off the flight, the nearby sheet remaining folded on the ground. The pilot observing the signal not to land, brought the helicopter to a height of about 10 feet and flew down the mall, climbing slightly and also turning slightly to its right. The main blades struck the flagpole on the left side of the aircraft.

The helicopter pitched down sharply and struck the ground 55 feet beyond the flagpole, on the bow of the left float. Almost immediately the bow of the right float also struck, the forward portion of the fuselage then telescoped severely and the helicopter toppled to the left. Persons nearby dragged out the occupants and put out a small fire.

Investigation

The flagpole which was struck is about 80 feet high. It was painted a drab bluish-green which would not contrast markedly with the general background. A flag about five feet by three feet at its top stood out with the wind towards the helicopter. One blade of the rotor hit 21 feet 8 inches above the ground and the other three inches higher, the first $3\frac{1}{2}$ feet and the other 4 feet from its tip. The pole was 8 inches in diameter at the point where the rotor blades made contact and showed only slight scarring. Both rotor blades were destroyed.



Although damage to the helicopter was extensive it was possible to check the continuity and functioning of all controls. Nothing was found to suggest that there had been any impairment of any control, and control difficulty was not suspected.

The pilot had a total of 4,800 hours of piloting, of which some 500 hours had been in helicopters. Between December, 1956, and the date of the accident he had flown S-55 helicopters 478 hours; S-58s 96 hours; and 47-H helicopters, the type involved in this accident, for 17 hours. His total time in 47-Hs was about 100 hours. He was regularly employed as a line pilot flying scheduled runs in S-55 and S-58 aircraft, and flew the 47-H aircraft only on occasional charter operations. Two of these charters had been during the preceding week.

Inspection and approval, by a company pilot, of the proposed landing site and adjacent obstacles indicated that the site was fully acceptable in all respects and was, in fact, regarded by the operator as suitable as CAA approved heliports used by the company in its scheduled operations in the New York area.

Reference to the sketch, which is to scale, will show that there was actually room for the helicopter to have passed between the flagpole and the nearest tree, located in the circle, 78 feet east of the flagpole.

The pilot testified that following his descent into the mall, over the wires and into the wind as shown in the sketch, he started to air taxi toward the company agent. The descent was steep using about 18 inches of manifold pressure at an airspeed of 30-40 knots. Almost at once he saw the wave-off signal. He applied the maximum engine speed of 3,100 r.p.m. and 28 inches of manifold pressure in preparation to climb and circle the area while waiting for the signal to land. At this time, the captain testified, he became aware of a 200 r.p.m. drop. About this time people on the ground noticed a slight lateral oscillation in the tail section. The pilot reduced collective pitch and nosed down to maintain speed. The r.p.m. came back to a normal 3,100 and he then again increased the collective pitch to resume climbing. The pilot's testimony continues that the r.p.m. again dropped about 200, whereupon he became concerned with finding a landing spot ahead. He did not start an auto-rotation type descent because of danger to people who were, so the pilot stated, moving into his path. Instead he decided to try to reach a point to the right of and beyond the flagpole which was clear of people. At this time the rotor blades struck the pole. No backfiring or engine roughness was noted at any time by the pilot, the surviving passenger, the ground agent, or by people on the ground.

Analysis

In the investigation of the accident nothing could be found to account for the claimed power loss. The engine ran normally under test, delivering full power, and without adjustments of any kind.

What seems quite possible is that the pilot, after accepting the wave-off, and applying more collective pitch to climb, did not co-ordinate his throttle motion with the motion of the collective pitch control. This would result in a decrease in r.p.m. which, however, should have been immediately recognised and remedied by using more throttle, as the proper synchronisation of these two controls should be second nature to experienced helicopter pilots.

Even if there had been a power loss caused by a 200 r.p.m. drop, for which no explanation was found, and which the Board finds difficult to accept, it is questionable if it would have been sufficiently disconcerting to cause the pilot to forget the flagpole ahead.

It has been mentioned that the tail of the aircraft was seen to oscillate (move laterally) at about the time of the attempted climb out. This also could have been caused by incompletely co-ordinated control, as helicopters with tail rotors require rather precise rudder control with any change of power if direction is to be maintained exactly. It seems most unlikely to have been caused by gustiness.

In attempting to arrive at the probable cause of this accident it seems desirable to keep certain circumstances in mind. When the pilot approached the company agent intending to land he was in full awareness of what was to be done. The wave-off, directly toward the flagpole, put in motion a new chain of events. The pilot had seen the flagpole from a considerable distance back, so he testified, but it is probable that its presence did not remain in his mind as an obstruction in the event of a wave-off which he did not expect. Presumably he continued ahead towards the pole until too late to avoid it and may well have misjudged his position relative to the pole.

PROBABLE CAUSE

The Board determined that the probable cause of this accident was the pilot's failure to attend to the flight path of the helicopter and avoid the known obstacle ahead after an unexpected wave-off.

C.54 Crashes immediately after Take-off

(Summary based on the report of the Civil Aeronautics Board, U.S.A.)

Just after midnight on 17th November, 1955, a Douglas C-54-DC crashed in a residential area of Seattle, Washington. The accident occurred immediately after take-off from Boeing Field. Twenty-eight of the 74 persons aboard were fatally injured and the remaining 46 received injuries of varying degrees. Although there were no injuries to persons on the ground, the accident caused substantial property damage and the aircraft was destroyed by impact and fire.

The Flight

The aircraft, on a flight from Boeing Field to Newark, New Jersey, departed at 2358 hours. The take-off appeared normal as the landing gear retracted and a right turn was begun. When approximately 300-400 feet above the ground the first reduction of power, from take-off to normal rated power, was made and about five of the 15 degrees of flaps extended, were retracted. At this time the No. 4 propeller surged and the engine r.p.m. increased to about 2,800. Unable to reduce the r.p.m. of No. 4 by reducing its power an attempt was made to feather the propeller; this also was unsuccessful. As the aircraft then began to descend take-off power was reapplied to Nos. 1, 2 and 3 engines and the power from No. 4 was further reduced. This action did not reduce the r.p.m. of No. 4 which surged again and increased to more than 3,000. The aircraft veered to the right and continued to descend. Realizing that a crash-landing was imminent the captain reduced the airspeed until the aircraft was nearly stalled and applied full power to all four engines. The aircraft continued to settle. It then struck a telephone pole and several trees before crash-landing in a nose-high attitude.

Fire and rescue equipment despatched to the scene arrived promptly and gave first aid to the survivors. Fire which followed the crash was quickly extinguished but not before extensive property was burned and the aircraft was nearly consumed.

Investigation

The accident scene was located approximately 2½ miles from and 300 feet higher than the take-off position of the flight. Evidence showed the aircraft was banked to the right when it initially struck the telephone pole with its right wing and horizontal stabilizer. Continuing along the impact heading of 210 degrees it came to rest approximately 650 feet beyond the pole. Along this path the aircraft struck several buildings, trees, and another pole, causing separation of both wings and tail and severe damage to the fuselage. The fire which broke out after final impact consumed major portions of the structure. Examination of the remaining portions of the wings, fuselage, and tail disclosed no evidence that indicated structural failure or malfunction prior to impact. Both pilots stated that they had experienced no difficulty except that associated with the No. 4 engine and propeller.

The No. 4 propeller, attached to the engine nose section, was located about 25 feet from the main wreckage. There was oil covering its barrel, the face side of all propeller blades, and the engine nose section. Examination disclosed that the propeller dome retaining nut protruded approximately one-eighth of an inch above the barrel dome bore and the safety cap screw was pressed against the corner of its safetying recess. The lockscrew was safetied. The screw was removed and its examination showed no evidence of bending or mutilation. After the nut and barrel were marked to show their original positions a check was made for tightness. The result showed that with a small drift and hammer the nut could be moved with comparative ease for at least 4½ inches in the tightening direction. The nut was then unscrewed and the dome removed to check the propeller blade pitch settings as indicated by the cam gear position. This revealed the cam gear lug was against the low pitch stop, or the normal low pitch blade angle setting. The blade segment gears were marked to show their positions in relationship to each other and to the cam gear. The propeller assembly was then further disassembled and examined after which it was removed from the accident scene for continued examination and testing.

Examination was directed to ascertain the individual blade angle settings. This disclosed that all of the eight spring packs which retain the segment gears, with their respective blades, were mutilated and displaced such that this retention was destroyed. Each of the segments gears was fractured at one of the spring pack recesses. This permitted free rotation of the blades about their longitudinal axis; however, the cam gear prevented any movement of the segment gears, enabling the investigators to determine the individual blade position at impact. Examination showed that the fifth valley from the low pitch end of the segment gears was lined up with the centre etched line on the barrel bore for the Nos. 1 and 2 blades. The No. 3 blade segment gear, however, had the sixth valley lined up with the etched mark. This showed that Nos. 1 and 2 blades were positioned one segment gear tooth less, or eight degrees less, than the No. 3 blade. Compared to the low pitch stop the No. 3 blade was positioned at 24 degrees, the normal position, while Nos. 1 and 2 blades were at 16 degrees, eight degrees less than the normal position.

To determine the possibility of oil leakage and, if existent, the amount of leakage from the loose dome assembly, the propeller was reassembled using replacement parts only where necessary; the dome and barrel assembly from the original propeller were used. The exact dome looseness was duplicated on a propeller test stand and oil was pumped into the propeller assembly at various pressures. The tests revealed that there was oil leakage at all pressures and that the maximum oil pressure obtainable was 200 p.s.i. (pounds per square inch), because of an 18-quarts per minute oil leakage past the loose dome. At this time the pump was operating under test conditions which would normally produce about 600 p.s.i. The test further showed the oil supply of the engine would rapidly be exhausted. (Oil capacity per engine is 20 gallons.)

The No. 4 engine was examined in detail. This revealed that the rear master rod bearing was in the process of failure. It also showed the front master rod bearing was beginning to fail. Examination of the bearing failures showed they were characteristic of those associated with oil starvation. Neither, however, had progressed to the extent that it would be expected to appreciably affect the operation of the engine or its power capability. The engine examination disclosed no other evidence of malfunction or failure.

According to company witnesses and records, the No. 4 propeller had been overhauled on September 7, 1955, and thereafter installed on another company DC-4. On November 11, 1955, it was removed as a result of a pilot roughness complaint applying to it or the No. 4 engine. The propeller was examined, repaired, and tested, after which it was installed by company maintenance personnel on the subject aircraft in the No. 4 position. Maintenance personnel stated a new propeller dome seal was used during this installation. At the time of the accident the propeller had accumulated 475 hours since the major overhaul and 20 hours since its installation on the aircraft.

During a portion of the 20 hours, the aircraft was flown to Kansas City where the captain took command of the aircraft and continued a military contract flight to McChord Air Force Base, Tacoma, Washington. This flight was uneventful except for a failure of the No. 4 starter solenoid at Billings, Montana. Because there were no adequate repair facilities there to correct this problem the passengers were offloaded and the engine started by taking off on three engines and airstarting the No. 4 engine. According to the crew, snow on the runway made it inadvisable to start the engine by fast taxi since it was doubtful if the aircraft could have been stopped safely thereafter on the remaining runway.

After arrival at McChord Air Force Base on November 13, 1955, the aircraft was immediately ferried to Boeing Field where the captain contacted the repair agency to replace the No. 4 starter solenoid, and to correct several other discrepancies noted and/or written up during the previous flight. The captain instructed the repair agency to examine the No. 4 engine to be sure it was not damaged in any way by the airstart. The crew noted an accumulation of oil on the right wing in the area of the engines and brought it to the attention of maintenance personnel for corrective action. Without cleaning the oil from the aircraft and running the engines to determine the source of leaking oil, the employees concluded from visual inspection that the leak came from the Nos. 3 and 4 propeller dome seals.

During the public hearing the mechanics and helpers who worked on the aircraft, and particularly on the No. 4 propeller, were called to testify. These witnesses were employed by the repair agency, some working as part-time employees and others as full-time In connection with the personnel working on the No. 4 propeller, the helper had recently been employed and the CAA certificated mechanic in charge had not replaced dome seals for three years. Neither employee was familiar with the experience and capability of the other or the prescribed procedure to be followed in correctly replacing the dome seals. These witnesses, through their testimony, showed there was no clear line of responsibility within the company nor were there reference manuals to define their specific work procedures.

Analysis

The crew stated that after reaching the airport on November 17 and talking with the vice-president of the repair company they were assured the aircraft was ready for flight. They stated that the maintenance forms given them were reviewed and showed the work ordered had been done. Because of conflicting recollections it is not known when this occurred, before or after the aircraft was taxied to the terminal.

Testimony of the maintenance personnel showed clearly that at no time after the aircraft was received for maintenance on November 14 were the engines run up. The Board is of the firm opinion that such a runup was essential to a vital part of the work performed on the Nos. 3 and 4 propellers and a responsibility of the maintenance agency. This was important in order to determine if the dome seals had been properly installed and if there were any leaks. It was even more necessary because the maintenance personnel had concluded that the original leaking oil came from the propeller dome seals, without first cleaning the engines and thereafter running them to be sure. Had the engines been run up following the work and the propellers exercised, the loose dome condition of No. 4 would have been immediately evident by leaking oil around it.

As shown by numerous expert witnesses, including a representative of the propeller manufacturer, it was published procedure to change the dome seals with the propeller blades feathered. This was not done and such omission is not considered to be acceptable maintenance.

It is evident that had the correct procedures been followed during the dome seal change, improper positioning of the blades would not have occurred. It is further believed that a thorough engine runup would have revealed this error.

The Board therefore is of the opinion that good maintenance practices and procedures dictated an engine runup. It was the responsibility of the repair company and only poor supervision, an over-extended workload, and poor maintenance procedures were responsible for the omission.

As the result of tests the Board is also of the opinion that considerable roughness would be caused by the improperly indexed No. 4 propeller blades, especially when the aircraft engines were warmed up before the aircraft was taxied to the terminal and while it was holding before take-off. Considering that all four engines were used during taxi and two engines were run up together prior to take-off, it is possible that the roughness would not be noticeable unless the crew carefully looked at No. 4 engine with their Aldis lamp and/or ice light. Had this been carefully done it is believed the roughness could have been detected.

As indicated, when the crew made the first power reduction the No.4 propeller did not respond. This was undoubtedly the result of insufficient oil supply to the propeller governor to actuate the propeller mechanism toward a higher blade angle. It is believed that sufficient feathering oil existed to start the process, but soon after the blades started to move the supply was exhausted. Exhaustion of feathering oil resulted in the blades returning to the low pitch setting with an attendant engine overspeeding. This sequence of events is substantiated by the observations of the flight crew when they noted a momentary reduction of r.p.m. and a decrease in rudder pressure during the feathering attempt and by the engine and propeller sound described by ground witnesses. Considering the drag shown by the engineering data, and that described by the captain, continued flight under these conditions was extremely difficult, if not impossible.

During the sequence of events the oil supply of the No. 4 engine became exhausted during the attempted feathering operation following take-off. As shown by the oil leakage tests, the total supply (20 gallons) was not entirely exhausted during flight but several gallons must have been lost before take-off. It is very probable that this occurred during the power check, the feathering check of the No. 4 propeller, and when that propeller was exercised. It is not known whether the leak could have been seen from the cockpit under the existing conditions and circumstances.

PROBABLE CAUSE

The Board determined that the probable cause of this accident was the excessively high drag resulting from the improperly indexed propeller blades and inability to feather. These conditions were the result of a series of maintenance errors and omissions.

Australian Accidents

The Finishing Run?

During 1957 there were a number of instances in which agricultural aircraft struck power lines whilst engaged in finishing runs carried out at right angles to the lines of primary spraying. The underlying reasons were not always the same, but there does seem to be a tendency to overlook the need for finishing runs in the planning stage of the operation, thus neglecting the significance of serious obstructions on the line of these runs.

There were nine instances of collisions with power lines during agricultural operations, and six of these accidents occurred when spraying was almost completed; the pilot was engaged in stripping, i.e. spraying the end strips of the area.

Following are two typical examples of the need, not only to make a careful survey of obstructions but to plan the whole operation, including the finishing runs, in relation to all obstructions which are observed at this time. Further, if you decide to change your plan of operation it is essential that you consider if your new plan takes into account previously insignificant obstructions.

During the morning of 26th October, 1957, an experienced agricultural pilot commenced a spraying task on a field of peas approximately 1,000 feet square near Gawler in South Australia. The pilot was well aware of the necessity for making a complete survey of the area before commencing work, the point having been emphasised by his employer and the lesson driven home by his reading of many articles in this Digest.

He noticed that the field was bisected north to south by a power line carrying 132,000 volts on 65 ft. poles. He also noticed that a subsidiary power line ran along the northern boundary of the field but discounted the significance of this latter obstruction in view of the fact that he was going to carry out the spraying operation in easterly and westerly directions. When the primary spraying was completed, the pilot decided to do two finishing runs towards the south along either side of the main power line which bisected the field. He flew to the north of the field and carried out a run down the western side of this line and returned again to the northern end for the finishing run down the eastern side. This time, however, as he crossed the northern boundary flying in a southerly direction, he collided with the subsidiary power line which he had noted before and dismissed from his mind. The aircraft was extensively damaged in the accident but, fortunately, the pilot escaped with only minor injuries.

In the first place it is apparent that the aircraft must have gone very close to this subsidiary power line at the commencement of the first finishing run but the pilot has stated that he did not see the line during either that run or on the run which culminated in the accident. It is considered that the basic cause of this accident can be found in the pilot's preliminary survey of the field. He noticed the subsidiary power line at this time and, having decided on the direction of his spraying runs, dismissed this obstruction from his mind. If, at this time, he had realised the necessity for finishing runs in a north to south direction he would also have realised that this power line did have a significance to his operation and that care would have to be taken to avoid it at the commencement of the finishing runs. Had the proper significance been given this power line at the initial planning stage it is reasonable to assume that, when the aircraft was flown to the northern end of the field for the finishing runs, this earlier realisation would have triggered in his mind a thought process which would have led him to look for these lines and avoid them.

An agricultural DH-82 aircraft was flown to a country property some 10 miles south-west of Narrandera in New South Wales one morning in October of last year. The task was to spray a wheat crop with weed-killer solution and operations soon commenced over a field approximately 5,000 feet by 1,500 feet. This field was bounded on its northern and shorter side by a road, telephone wires and power transmission lines. The pilot made a careful survey of the area, both from the ground and from the air before starting operations and he noticed that the power lines left the line of the road and crossed the north-eastern corner of the field. He decided to conduct the primary spraying in northerly and southerly directions.

By about 0830 hours there were only the two finishing runs in this field left to be done and the first was carried out along the southern boundary in an easterly direction and the pilot then flew towards the northern boundary with the intention of doing the last finishing run towards the west. He remembered that the power lines crossed the corner of the field which he was approaching and he descended to a height and towards a point which he estimated would take him beneath the power lines and on to the line of the final finishing run. Before he saw the power lines the aircraft struck them, slid along them, overturned and fell to the ground. The aircraft was substantially damaged and the pilot suffered severe shock but no physical injury.

There was a 750-foot span between the poles supporting these power lines in this case and it must always be expected that the lines themselves will be most difficult to see from an aircraft in flight unless they are of unusually large diameter. This pilot did not gauge the position of the power lines by first locating the supporting poles but descended into an area of known danger in the hope that he would see the lines in time to avoid them. It would have been far wiser to have approached the area at a safe height, firmly established the position of the power lines and then commenced the finishing run with that knowledge. It is considered that this pilot's method of approach into such a hazardous area was the real cause of this accident.

That Unseen Tree Again

During the morning of 15th June, 1957, while engaged in unauthorised low flying in the vicinity of the home of the pilot, a DH-82 struck a tree and crashed. The pilot and his passenger were injured, the pilot seriously, and the aircraft was wrecked.

The DH-82 was owned by the local areo club and had been obtained by the pilot for a flight over his own property and that of his passenger, who was a neighbour. The properties were located in a generally flat area which was extensively covered with tall scrub. On arrival in the area the aircraft was descended to a low height and flown over the respective homes of the two occupants as well as other houses in the vicinity. It passed low over a house headed in a northerly direction watched by two people nearby and then, without deviating from its heading, struck a lone dead tree standing 600 feet from the house.

The aircraft rolled to the left and dived into the ground 220 feet beyond the tree. It then turned over as it skidded a further 40 feet and came to rest inverted and heading back along the flight path.

Weather conditions were fine with unrestricted visibility. The dead tree was approximately 30-40 feet taller than the surrounding scrub and, as it was of substantial girth, it should have been readily seen by the pilot. Both he and his passenger stated that they did not see the tree and the absence of any sign that an evasive manoeuvre was attempted supports this contention and leads to the conclusion that the pilot was paying insufficient attention to his flight path.

In-flight Structural Failure of Kookaburra Glider

As an ES-52 Kookaburra glider pulled out from a dive over the glider field near Mildura, Victoria, during the afternoon of 29th December, 1956, its right wing broke off and the aircraft crashed onto the field killing both of its occupants.

The glider was winch launched at about 1355 hours E.S.T. on the first flight for the day. Weather conditions at the time were cloudless and clear, ground level temperature 80°F and the wind from south at about nine knots. A flight instructor occupied the rear seat and a trainee pilot who had not soloed, but who it is believed was close to that stage in his training, was in the normal pilot position. Dual controls were fitted. The launch was uneventful and the glider soared to an estimated height of 2,000 feet close to the field where it commenced a sequence of manoeuvres frequently performed by the flight instructor and which usually terminated in a loop. Several straight stall and recovery exercises were closely followed by what appeared to the onlookers to be the usual spin, on this occasion made to the right. This manoeuvre was entered from a straight stall. The spinning stopped on completion of two turns and the pull-out from the subsequent dive, which was in all probability the entry to a loop, progressed to the point where the nose was just above horizontal when the right wing was

seen to break off and a loud report was heard. The glider then spiralled steeply to the ground.

Except for a short section, to which was attached the fin, rudder, and left tailplane and elevator, the fuselage disintegrated on impact with the ground. The right wing was located some 800 feet distant from the main wreckage and scattered about this point also were many fragments of the right tailplane and elevator. The detached wing was intact and had received only minor additional damage on contact with the ground. Eyewitness evidence indicated that the tailplane and elevator were shattered by the wing as it folded back and damage to the trailing edge of the wing was consistent with such a sequence of failure.

The wing spar, a continuous member of wooden construction, failed close to the fuselage pick up point on the right side. The failure path through the rest of the wing structure was approximately through the root rib position. The nature of the fractures of the spar booms indicated that the spar had failed under upward or positive bending loads. One line pursued during the investigation was the possibility that the wing structure had been weakened by damage sustained on some occasion prior to the fatal flight. To this end a detailed examination of the wing and the mating portions of the centre section was made but it did not disclose any evidence that the integrity of the wing had been affected in this way.

The broken spar was subjected to scientific laboratory examination which revealed no evidence that the spar had suffered damage prior to the in-flight failure and also confirmed that the primary failure of the wing was the failure in tension of the lower or tension boom of the wing spar. The labatory examination included tests of specimens of timber taken from each lamination of the spar booms. Based on the results of these tests an analysis of the strength of the spar was made from which it was concluded that the spar should not have failed under loadings due to an acceleration of less than 8 to 9 g. No evidence of malfunctioning or failure in the flight control systems was found during the examination of the wreckage but the extent of the destruction of the fuselage rendered this examination inconclusive.

Although all of the eyewitnesses described the manoeuvre performed by the glider as a spin, flight tests of a Kookaburra carried out by the Department in the course of the investigation showed that this might not have been the case. It was found that the glider would enter a spiral dive readily if full rudder was applied when it was just above stalling speed and the control column was held short of the full back position, a condition likely to occur during an attempt to spin by an inexperienced pilot. On one occasion a spiral dive developed from a normal spin.

The spiral dive resembled a spin in all respects except that the airspeed did not stabilise at a value in the region of the stalling speed, as is the case in a spin, but the glider continued to accelerate rapidly throughout the manoeuvre. In one spiral dive entered at 35 knots the speed reached 80 knots in the second turn and exceeded 120 knots in the fourth turn. With the additional speed which is gained during the recovery, dive speeds of 100 knots or more can be expected following a spiral of two turn duration.

Two of the standard 6 lb. ballast weights were carried in the crashed glider and it was estimated that its centre-of-gravity was located at approximately 1.25 inches inside the forward limit. The test glider was loaded in a similar manner and in this load condition full nose up elevator trim was required for trimmed flight at the normal gliding speeds of 40-45 knots. With this trim setting it was found that extremely high forward pressure on the control column was required during recovery from a dive at 110 knots to prevent the loading from exceeding 4½ g. It was apparent that if the forward pressure on the control column were released at this time loadings in excess of the strength of the glider would result. In a dive at 120 knots with the elevator trim control in the full nose down position the control column was released and the maximum loading recorded during the resultant pull-out was 3 g.

There is little doubt that the manoeuvre immediately preceding the pull-up during which the wing failed was intended to be a spin and that it was entered intentionally. The flight tests showed that a high speed could have been inadvertently attained during this manoeuvre; they also showed that a full nose up elevator trim condition, as was likely on the fatal flight, would produce forces at this high speed which, if not opposed by the pilot, could result in structural over-loading of the glider. It was concluded that during the pull-out from the dive the glider was subjected to a manoeuvre load in excess of its design strength. On the available evidence it could not be determined whether this load was the result of some action of the pilot, either deliberate or inadvertent, or some other factor.

The instructor pilot had 104 hours of pilot experience of which 35 hours was flown in light aeroplanes and the remainder in gliders. At the time he commenced acting as instructor in gliders he had a total of 17 hours glider pilot time and subsequently he had flown 92 hours, all on the Kookaburra.

Chipmunk in Fatal Collision with Power Lines

Late in the afternoon of the 20th October, 1957, a private pilot decided to take three of his friends for short flights in a Chipmunk aircraft owned by the Canberra Aero Club. During the second flight the aircraft struck power lines and crashed. Both occupants were seriously injured in the impact and the pilot later succumbed to these injuries

The first flight, which occupied about 20 minutes, was made from the aerodrome at Canberra towards Tharwa, 16 miles to the south, thence along the Murrumbidgee River at a low height in a north-westerly direction and then back to the aerodrome. During this first flight the aircraft was observed flying low along the river by a number of eye-witnesses.

The second flight commenced almost immediately and followed much the same pattern as the first. The aircraft was again observed by the same eyewitnesses as it flew low along the Murrumbidgee River but this time, instead of overflying the power lines which cross the river at the Pine Island Reserve, as it had done on the first flight, the aircraft was seen to fly directly into the power lines and crash onto the river bank.

From the eye-witness evidence relating to the flight path of the aircraft it is apparent that the pilot flew into the power lines without seeing them. It is not known whether he was aware of these power lines or whether he saw them on the previous flight and then forgot about them. The Canberra Aero Club rules clearly prohibit low-flying in club aircraft unless an instructor is aboard and, even then, great care is taken to brief pilots on the location and nature of serious obstructions in the low-flying area. This flight was properly authorised but the authorisation did not contain any permission for low-flying.

The low-flying was carried out in the approved low-flying area at Canberra but the carriage of a passenger amounts to a contravention of Air Navigation Regulation 242(1)(c). It could even be said that this aircraft was not engaged in flying training in the accepted sense and for this reason any flight below 500 feet was in contravention of Air Navigation Regulation 133(2)(b).

These Regulations do not prohibit low flying but they stipulate the conditions under which low flying shall be conducted. The purpose of imposing such conditions is simply to protect lives and property. These conditions should not be, but often are, disregarded with unfortunate results. If this accident means anything then those Regulations that are aimed at the protection of life and property cannot be set aside without exposing someone to a very grave risk. Clearly the risk is not worth taking. Nevertheless such risks are taken and the simple reason is a lack of self-discipline.

Do You Still Know?

1. **How to determine position in miles abeam a non-directional beacon or broadcast station from a knowledge of change of bearing with time?**
2. **What type of information is contained in Section 2 of the AIREP and when it is transmitted?**
3. **The recent experience requirements for IFR flight and the use of radio aids?**
4. **That there is wisdom in a pilot wearing his seat belt when flying with the auto-pilot engaged?**
5. **What considerations affect determination of the critical point for an overwater crossing?**

INCIDENTS

Check those Tank Vents

On 25th June, 1958, a DH.84 on a flight from Deniliquin to Echuca forced landed six miles from its destination as a result of a fuel stoppage.

Approximately 30 minutes after take-off, engine trouble was experienced and a check revealed that the starboard fuel tank was half full but the port tank was empty. Both cocks had been on in order that fuel could be drawn from both tanks. The port cock was immediately turned off but the engine failed to recover, so a forced landing was carried out.

Investigation revealed that the breather hole in the filler cap on the starboard fuel tank had been blocked by a large insect. This prevented air from entering the tank as the fuel level decreased, and so caused a decrease in pressure in the tank which prevented fuel from flowing to the engine.

This danger had been recognised long before this and Air Navigation Orders, Part 20, Section 20.2, paragraph 20.2.5.3 calls for a check of the tank vents daily before flight. It requires a continuous conscious effort to keep abreast of safety requirements and it is clear from incidents such as this, that there are some who ultimately accept the easy road. To those with a flagging interest in healthy aviation we can only urge that time off be taken to reflect on the possible consequences of sometimes ignoring the advice continually being offered.

It is not often that tank vents become blocked but, as this incident shows, it can happen and a forced landing can be most embarrassing if not highly dangerous.

Leg Trouble

On 3rd January, 1958, the captain of a DC.4 reported difficulty in closing the nose wheel doors soon after take-off from Port Moresby. The aircraft returned and after Air Traffic Control had confirmed that the nose wheel doors were open a landing was made without further incident.

During the climb after taking-off from Port Moresby on 23rd February, 1958, the captain reported having heard a heavy thump in the nose wheel well when the undercarriage retracted and the red warning light remained on. The nose wheel could be seen to have failed to fully retract. The gear was recycled and on retraction the red light went out. After confirmation from ground observers that the undercarriage was functioning normally, a landing was made without incident.

The investigation revealed that in both instances at Port Moresby the nose gear strut was failing to extend fully and was fouling the saddle assembly during retraction. Loosening of the gland nut freed the nose gear strut and indicated that the fault was due to the gland of the nose wheel leg being over-tightened during overhaul. To obviate this type of defect the operator has revised the gland nut tightening procedure.

Two minutes after take-off from Sydney on 19th April, 1958, the captain of a Viscount reported failure of the nose wheel to fully retract and requested landing instructions. Investigations revealed that the nose wheel nacelle door actuating hook was bent and failed to engage the roller on the door actuating beam. The front of the hook was apparently bent by the aircraft towing bar. The operator is modifying the towing bars and personnel have been alerted concerning the fitting of towing bars.

Unserviceability Markers

A recent incident has highlighted the need for greater care in the choice of runup positions at country aerodromes.

The unserviceable portions of a runway had been marked off with a red and a white flag. Two regular public transport aircraft taxied past the flags and commenced to runup with the result that the red flag was blown away and as it was raining at the time the white flag became camouflaged with mud.

A light aircraft taxied out for take-off and paused at the position of the red flag. When moving-off after runup the aircraft struck the camouflaged white flag with resultant damage to the propeller.

When running-up or manoeuvring in the vicinity of markers you are urged to be careful so that they are not blown over or discoloured with dirt by the slip-stream. Your thoughtfulness in this regard can avoid inconvenience to others and possible damage to aircraft.

ELECTRICAL SYSTEM

Insulated Panel Connections

Charred Panels Result From Overheated Loose Connections

the Situation

LOOSE CONNECTIONS, which invariably follow poor design practices in the manufacture and installation of electrical equipment are in themselves insignificant, but cause an immense amount of costly damage to aircraft. The preponderance of electrical equipment used in modern aircraft and dependence placed upon its proper functioning, make good design practice mandatory. This is covered adequately in most aircraft manufacturer's design handbooks.

The propensity for laminated phenolics and other insulating plastics to "cold flow", has too often been overlooked when designing electrical equipment. Thermal conditions coupled with vibration, conspire to loosen mechanical connections unless ample precautions are taken to prevent its occurring.

the Hazard

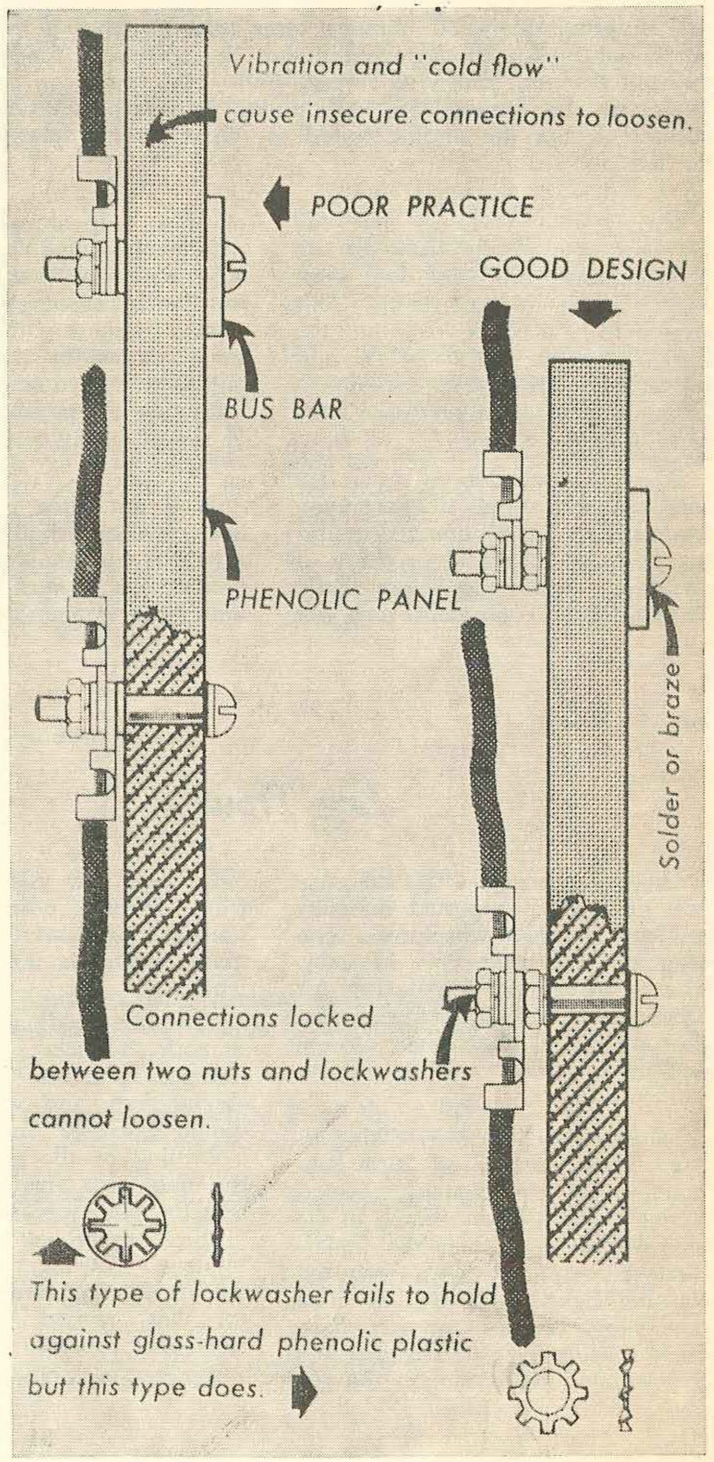
A loose connection in a primary circuit can start a chain reaction of failures in a number of dependent secondary circuits. Imperfect connections in DC circuits of high current capacity, will cause excessive heat, charring of insulating panels, and the consequent probability of fire.

the Fix

Positive locking of electrical connections between two or more threaded nuts secured by lockwashers will prevent their loosening.

PRECEPT

Design to encounter with safety, the impact of objects, rough handling by men, and the effects of natural phenomena such as: vibration, corrosion, fatigue, which are likely to be met in service.



By (Courtesy Flight Safety Foundation, Inc.)