GLIDING AND POWER FLYING

COMPASS BOOKS

GLIDING AND POWER FLYING

Compass Book No. 5

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PLATE I. "Ridge Soaring"

GLIDING AND POWER FLYING

"String-bag"

With Drawings by
STANLEY SPROULE

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CHAPTER ONE

INTRODUCTION TO FLIGHT

Being an account of a flight in a glider which those who read this book may one day duplicate for themselves.

It was a bright, windy day in spring. At the foot of the ridge, on the undulating chalk-land which rolls westwards into the valley of the Thame, a dozen gliders awaited their turn on the launching winch. Overhead were others, pinned against the snowy clouds, like kestrels searching for a prey. They rode the slope wind—the keen, swift breath from the south-west which had swept over the heel of Cornwall, over the moors of Devon, over Wiltshire and Berkshire, to strike the steep face of the Dunstable ridge, which sent it rocketing skywards like the ricochet of a bullet.

Up there in the sun, the pilots found it rough. The wings of their craft shuddered in the gusts, especially over the bowl at the northern end of the ridge where the air seemed to gather before its onrush into the sky. There were nearly five hundred feet of tossing, invisible eddies between the keel of the lowest glider and the rounded green top of the hill. Every gust lifted the machines a few extra feet, and the more experienced pilots were easing back their controls, wringing every extra foot of height out of the momentary increase in the wind.

But one particular pilot was not content. He saw the launch of other gliders below, saw them skate over the ridge and come climbing up to his own eyrie. He sensed their enjoyment of the restless struggle through the rising air, but he knew that unless they looked elsewhere, they were bound by invisible chains to a brief space in the sky, a channel of air about a mile long and a few dozen yards wide which followed the contours of the ridge below. He was not content with so narrow a sea, and so his eyes were ever searching for one of the purple-based clouds which came driving down-wind, to rob the landscape of its sunshine, and more particularly provide him with a spout of rising air into its folds. If such a cloud came within reach, and he could find the invisible funnel leading up to it, he could break these chains which limited him to a mere eight hundred feet of height and a few hundred yards of space. He could circle up within the funnel, break into the cloud itself, and go sailing downwind until Dunstable was a mere memory. He was prepared for it, prepared to "go away," as these glider folk call it. Half an hour before he had been arranging the last details with his partner and half-owner of the glider which he now flew.

"I ought to get as far as the Norfolk coast," he said. "It's a hundred and ten miles to Cromer, and I should average forty miles an hour in this wind . . . say three hours flying.

His partner agreed. The conditions were good, and unless the glider was let down over the flat country to the east of Cambridge, where the turbulence of the air might be less than it was over the rough country to the west, then Cromer on the north-eastern tip of Norfolk was a reasonable goal.

"As soon as I see you get away from the ridge," concluded his partner, "I ll start after you in the car. If I lose you, I'll wait at the White Swan in Mildenhall until you 'phone. It's about half way."

Then the cloud came—came racing up the Thame Valley along the edge of the Chiltern Hills . . . a monster with towering white battlements which rose into the frozen solitudes of the upper air twelve thousand feet high. Around its crest was a wispy scarf of a million ice crystals. It was the sort of cloud of which glider pilots dream, half afraid, half fascinated, and invariably speculative as to the strength of its updraughts.

He saw it ten miles away, and guessed that it would pass the southern end of the ridge beyond the Whipsnade Zoo, perhaps a couple of miles from his position above the bowl. So he set off and rode towards it along the slope wind. The up-currents were more feeble here and the air smoother. Above the Zoo he was down to six hundred feet and the black base of the cloud, which he now saw was suspending long dark bars of driving rain, was still a couple of miles away. He was already at the southern limit of the lift of the slope wind, and was forced to rely on keeping his valuable six hundred feet while the shadow of the cloud approached.

Out ahead was the Ivinghoe Beacon, a bold outpost of the Chilterns, which, if he could reach it, would make the cloud safe for him. But between him and the knoll there was a shallow valley which in this slant of wind would be an ocean of downdraughts.

As he watched, the curtain of rain from the base of the monster stole the beacon from his sight, and at the same moment something happened to his aircraft. It shuddered, a tremor running through the fuselage as though a great force had laid hold of it, and then passed on. It was the clue the pilot wanted. He threw away the security of the ridge, and flew west over the lower slope towards the black area of rain. He flew out of the lift, cutting through momentary calm air and losing height at over five feet every second. The sunlight drained out of his cockpit and left him in a dark, sinister world, still calm, but with a tense, resonant feeling as though the atmosphere was stretched tight as a violin string.

He was cutting things fine, for unless the cloud reached down for him within the next minute, he would be so near the ground that escape would be impossible. The dark fury of the rain was not more than half a mile away; the whole land to the west was veiled by it, and only out of the right-hand side of the cockpit could he see under the edge of the storm the bright light of the spring morning.

Then it came, a clean, quick blast under both wings simultaneously. It was as though he had been sitting in a stationary lift and someone had pressed the starter button. It sent the needle of the rate of climb indicator on his dashboard the whole way across its dial. Out of the corner of his eye, he saw that it was kicking against its stop at twenty feet per second rise. He hung on, flung for a moment on to his side, as a surging tide of air bore him upwards. The whole atmosphere of the slope underneath him was being undercut by the advancing storm and forced upwards.

He rode it out precariously for a few seconds, slamming the control column to the extremes of its travel to correct the gusts which hit first one wing and then the other. Had he looked at his instruments, he would have seen that his speed was jumping from thirty to sixty miles an hour and that his rate of climb was varying from zero to the maximum which could be registered on the dial. But he was fully occupied in working his aircraft through a turn to bring him parallel to the advancing wall of rain. He had the strongest aversion to entering the rain itself. It was rough enough outside, without tempting providence and being blinded into the bargain.

By the time he had levelled off and was flying south along the face of the storm, he saw that the altimeter was reading fifteen hundred feet. He had climbed nine hundred feet in perhaps thirty seconds, which was fast for even a violent cold front.

The air was smoother now. He was half a mile ahead of the wall of storm, although the wispy edges of the main body of cloud still overshadowed him. He was rising towards them, towards the purple-black interior of the cloud itself at fifteen feet every second. He had been so shaken in that first minute, as the edge of the front engulfed him, that he felt the interior could be no worse. The air here was already better, and the rate of climb had settled down to something which was smooth and positively pleasant. He switched on his electrically-driven blind flying instruments, and put the aircraft into a gentle turn. The base of the cloud seemed to be coming towards him. A patch which was darker than the rest lay immediately overhead. Soon he was circling beneath it, and was aware that he was being drawn into an inverted bowl. The base of the cloud which had looked so flat from the ground was concave, so that he was soon looking down at a dark circular disc below which was the earth. The rate of climb was steady, but the altimeter had moved round to 3,000 feet, its needle climbing slowly across the dial.

The bowl was narrowing, and looking out towards his wing tips, he saw the outer wing was cutting through its wall, appearing and disappearing in a thin swirl of grey vapour. In another second it seemed as though his little cockpit was a room in which somebody had drawn the blinds. Even the instruments were drenched in twilight and when he looked out, all he could see was the gracefully-rounded nose of the fuselage in front of him. The rest was a purple-grey gloom, full of movement and sound—the flute-like sound of his own passage through the air.

He hunched himself low into his seat, felt the security of the parachute strapped to his back, and watched the instruments with all the care of a wild duck watching her young. Every now and again he made fractional movements of the control column, once to regain lost speed, once to correct a skid which had been revealed by the needle of the turn-and-bank indicator, and all the time he had half an eye for the altimeter. Four . . . five . . . six thousand feet . . . he was climbing at the rate of more than a thousand feet a minute, and the air was still smooth.

At eight thousand feet he looked through the perspex panel of the cockpit, along the edge of the wings, which were almost level with his eyes. A long, straight strip of gleaming white ice, as broad as his hand and perhaps an inch deep, ran away on either side; its glare had caught his eye. There was rime, too, along the thrust-out tube of the Peto head, and more rime along the metal framework of the transparent cockpit. It was time to get out of the cloud—high time, for when he looked again the ice had thickened, and a little more of it would destroy the lift of his wings, and a little more after that would send him hurtling down out of control.

He centralised all controls, and as the compass ceased to swing, he eased the glider on to a north-easterly course. It was, he remembered, the shortest route out of the cloud, and should bring him once again ahead of the storm which was raging below. But now the air was no longer smooth. He had passed out of the comparatively calm funnel which was rising through its centre, and was moving swiftly into torrents of wild air, places where up-currents lay alarmingly close to almost equally powerful down-currents. Once he saw his wing tips flex, as though twisted by an unseen hand, and all the time the fuselage groaned under the strain. His head hit the transparent roof, and at the same moment the air speed indicator flickered, kicked, and sagged back to a mere twenty miles an hour. The needles of the other instruments began to career round their dials, and the wind outside came in sobs and shrieks, while violent motions of the aircraft flung him against the sides of the cockpit. Convinced that he was out of control, yet seeing nothing in the grey-blue darkness, and deserted by his instruments whose gyroscopes had apparently toppled, he took the correct action. He did nothing—if it is nothing to hold all the controls central.

In another minute—perhaps less—there was a bright patch ahead of him, and then, dramatically, like the opening of a camera's shutter, a blinding light flooded into the cockpit so that he was compelled to half close his eyes. Peering forward, he expected the blue sky, and found it at a strange angle through a side panel. He was on his side, spiralling to the left, and the cloud was behind and above him, its domes of glistening white towering into the infinity of the blue.

He righted the aircraft, and then realised why he had seen nothing when he looked ahead. The front panels of the hood were frosted. His whole aircraft was frosted. Icicles sprang from every projection, and as the warm sun began to melt them, they fell off with a curious tinkling sound.

It was a relief to be free again, to be sailing in an ocean of peace where the air was unrippled and the sun sent the ice slithering from the wings.

He glanced at the altimeter and saw that it stood at 8,400 feet. He hadn't lost much height in that wild retreat from the toils of the cloud. Turning round, he saw the cauliflower head from which he had emerged. It was about five times as tall as St. Paul's Cathedral and it looked as solid.

Down below, the tops of lesser clouds bulged upwards towards him, some of them almost at his own height, others —like growing children—mere bubbles whose crests were thousands of feet below. Between the clouds he saw the pattern-work of the earth—the neat rhomboids of the fields, the spider-like tracery of a railway line, the silver glint of a lake, and then the roofs of a town. To the west, the mighty cloud from which he had come filled the sky. He saw that he had scarcely climbed through half of it. One peak about a mile away looked at least five thousand feet above him, and was probably more. He was glad that he was out of it, that he had won his height, and he could now turn on his journey with the feeling of security which great height in a glider gives to its pilot.

Setting a north-easterly course, he flew straight in smooth, sunny air. His air speed was forty-five miles an hour, and his sink three feet per second. With a wind behind him which could scarcely be less than thirty-five miles an hour, he calculated that he could glide in a straight line for at least fifty miles, even if he found no more lift. It meant that he could reach Newmarket, and with luck another dozen miles beyond, where the church at Mildenhall would mark the halfway point.

The roofs of Royston, with the long straight of its Roman road, and the green oasis of the Cam valley gave him his position. He was down to six thousand feet now, and had come twenty-five miles. Moreover, he was south of his course, probably due to a veer of the wind into the north, which might be expected at this height. On his left, he could see the spires of Cambridge, and beyond them the interminable quartering of the rich dark fields and the silver lines of the dykes, stretching to the ultimate horizon where a gleam of brighter light suggested the southern end of the Wash.

A quarter of an hour later he was flying into a rapidly-clearing sky. To the south there was a cloud street along the line of the Suffolk downs . . . useless if he was to reach the Norfolk coast. The arc of the northern horizon contained a mere handful of fleecy cumulus, and only one of them looked as though it might help. It was two miles away in the direction he wanted to go, and he made for it with sinking hopes. Not since he had left the big cloud at over eight thousand feet had there been so much as a tremor in the air. Every yard he had come had been at the cost of another inch of height. It was strange how the boisterous conditions over Dunstable had given place to the stability usually associated with a windless evening.

He reached the cloud with two thousand feet in hand, felt a tremor of the wings under its darkest portion, saw the needle of the rate of climb indicator hesitate, and with a feeling of thankfulness threw the aircraft into a circle. For the first few minutes he only succeeded in checking the descent. The needle remained obstinately at zero. But by gentle coaxing, flying at a bare thirty-five miles an hour, at which his glider was at its most efficient, he persuaded the instrument to show him a climb of three feet per second. Circle followed circle, and with infinite slowness the altimeter swung from two thousand to two thousand five hundred feet. Then for a reason he couldn't explain, the rising column of air faded away, and once again the needle on the dial fell back. It was followed in a moment by a gentle downdraught which began to steal with increasing speed the height he had so laboriously won.

There was nothing left but to desert the cloud and hope for better things further on. Mildenhall was in sight, and above the little town a wisp of white vapour was forming. This was what he needed—a new cloud with the activity of its rising currents. He reached it with only a thousand feet left, but this time there was no doubt about its friendliness. A column of restless air took hold of the wings as he flew over the church, and a moment later he was circling once again in a lift of five feet per second. Later, he worked it up to seven feet a second while, overhead, the cloud grew. In ten minutes he was at three thousand feet and entering the bottom of the cloud itself. He entered it, to be enveloped in its mists, and gently rocked on its wavering breaths. For another five hundred feet he flew on, when the lift gave place to rougher air in which he began to lose and gain height alternately.

The cloud had done its best for him. He flew out of its side at 3,500 feet, and found that while he had been climbing, he had drifted nearly another dozen miles to Thetford. Now he could see the coast from Harwich round to Cromer itself.

With luck, he could still make the forty miles which separated them.

Yet he was in desperate straits again twenty minutes later as he swung low past the city of Norwich. He was so low that he dared not fly over it, lest a sudden downdraught should precipitate him into its streets. A few miles ahead he could see the runways of an aerodrome, and with eight hundred feet in hand, he thought he could reach it and make an emergency landing. Over the aerodrome buildings, he had only three hundred feet remaining. The last chance, it seemed, had gone, and it was then that a bubble of hot air rising from the concrete standings in front of the hangars broke away and smote the keel of his aircraft with a powerful surge. For an instant, he was unsure whether to continue his circuit of the field and land, or try once again to retrieve his position. The thermal would be weak and narrow at so low a height.

He decided to risk it, and for a few minutes he saw the roofs of the hangars revolving round him at unpleasantly close quarters. Then gradually he realised they were drawing away. The roughness of the air was smoothing out a little, and the needle was once more climbing across the face of the altimeter. At five hundred feet he was climbing at four feet per second. At eight hundred feet this had increased to seven feet, and at fifteen hundred he found himself in a superbly developed thermal of twelve feet per second. He could see faces on the ground turned upwards, looking at him. No doubt they thought him mad . . . a pilot without an engine who had been obviously about to land, and who had climbed back into the sky again as though it were the most everyday occurrence in the world.

At each circle the aerodrome receded as he drifted downwind, and at last with three thousand feet in hand he left its dying eddies and turned again to the north-east with Cromer only fifteen miles away. He could already see its roofs and the white line of the waves along its beach. It was a straight flight without the possibility of further worries, and then, just when he didn't need any help, he struck another thermal over a village just short of Cromer. He drove through it, and pushing down the nose of the aircraft, put up the speed to sixty miles an hour and swept over the town to cross the long level beach.

His partner with the car and its trailer was two hours behind.

"What sort of a trip did you have?" he asked.

"Wild to begin with . . . and afterwards very tame . . . too tame in fact."

"Funny," said his partner, "but the sky cleared after leaving Newmarket. I thought you'd never make it."

"Nor did I," he replied. "I was saved by a thermal from an aerodrome just this side of Norwich—probably from the cookhouse."

The secrets by which such flights as these are made, and those things which lead up to the mastery of them, are the substance of these pages. It has been my lot for nearly six years to fly aircraft with engines developing up to two thousand horse-power, and before that I flew aircraft without engines at all. In those years, and the hundreds of hours flying which they involved, I don't think that once I wished I was on the ground. There have been bad moments certainly, times when it would have been a relief to have been sitting safely in front of a fire. But these feelings were momentary, and the next morning the call of the sky was as strong as ever.

The air is like that. Its attractions get into the blood, as the sea gets into the blood of the sailor. Although a storm may frighten him, there is a grandeur about it which sounds a chord in his heart, raising his spirit to new levels, and calling out the best in his character.

But before a sailor is fit to be captain of his ship, or an airman the captain of his aircraft, it is necessary for him to know his trade—and the trade of the air is as wide as the heavens themselves. It is not even necessary to fly before the first lessons are learned. In fact a great deal of important knowledge can be acquired from observation and study on the ground. How many people, for instance, know the portents of the cirrus clouds in the sky and the lowering banks of stratus; how many can read the mountain ranges of cumulus, or assess the path of the wind as it strikes the face of a hill? In an age when men fly as readily and easily as they drive motor cars, many of them still know little of the mechanics of flight—of even the elementary secrets discovered four hundred years ago. If a man is to be a good pilot, he must understand all these things. It doesn't matter whether he intends to fly gliders—or sailplanes, as they are more often called—or powered aircraft. Many a time, as I have sat behind two thousand horse-power, I have been glad to have had experience as a glider pilot. The dirty weather ahead became mentally clear, however dark its physical body.

Let us, therefore, begin at the beginning and see why aircraft fly at all, and then examine what every man and woman must do before he or she is capable of taking over the controls as captain of their own plane.

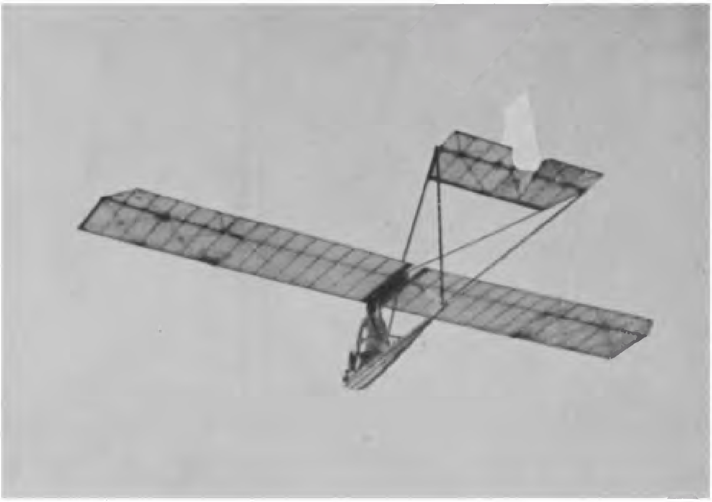


PLATE 2. A pupil takes a "high hop" in an open "Dagling." This is a type frequently used for primary instruction.

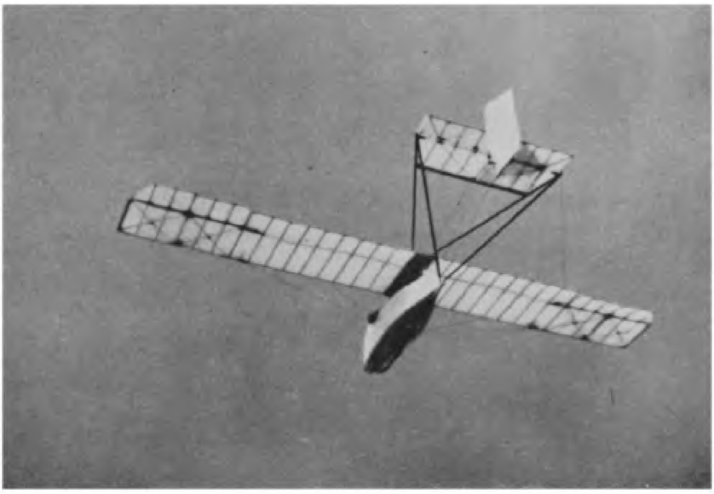


PLATE 3. This is a "Dagling" with a nacelle built around the pilot. The result is a greatly improved performance. Training up to the "A" Certificate is often taken in this class of glider.

PLATE 4. The crew on the elastic launching rope have done their work. The primary glider with its pupil takes off for a "low hop."

PLATE 5. The Cadet, a secondary training aircraft suitable for ridge soaring. Its gliding angle is in the neighbourhood of 14 to 1.

CHAPTER TWO

WHY AIRCRAFT FLY

Being the story of a home-made glider, and an explanation of the forces which act upon the wings and the control surfaces of an aircraft. A description of how to make a model glider which will prove some of these things.

SHE had a wing span of twelve feet. The pilot stood in a hole in the centre of the fuselage, his hands grasping the frame on either side. The idea was that he should run with it down a steep slope, and, as soon as he was airborne, swing his body from side to side so as to control the direction and stability.

With the help of another boy, he carried it to the river, where a steep bank fell away towards the water. If the flight was successful, it would terminate twenty-five yards away in the centre of the river—a point of small importance compared with the triumph of flying. Indeed, its owner-pilot felt in his heart that the first flight would probably be the last. The hours spent in the school workshop, to say nothing of a term's pocket money on fabric for the wings, would be written off. But what did it matter—he was going to fly.

He balanced the machine from either arm, struggled for a moment to hold it steady against the wind, and began to run forward. Two, three paces . . . and his feet left the ground. A gust got under the wings and lifted him higher. He was four feet up, and the slope was slipping away beneath him. For perhaps two seconds he was conscious of his conquest of the air—and then the inevitable happened. A wing dropped, the whole contraption slipped sideways, fell towards the earth, and suddenly disintegrated in a smother of smashed woodwork and torn fabric.

The boy disentangled himself from the wreck, stood up and looked at it, smiling. Then he glanced up the slope towards the top of the bank where his friend still stood in a state of shocked alarm. Measuring the distance with his eye, he concluded that he had flown ten yards.

I consider that this enterprise, launched at the age of twelve, was the best work I ever did at my preparatory school. I had the right idea. I appreciated that a flat surface inclined at an angle to the wind had potentialities for flight. As far as it went, the theory was excellent, and after thirty years its truth still holds good. It is the point from which we might well start our investigations into how heavier-than-air machines fly.

Take a piece of flat board. Go upstairs and fill the bath with water. Then plunge your hand into the water, draw the board beneath the surface and pull it edgeways from one end of the bath to the other. If the board is inclined upwards, it will be forced to rise to the surface. If the inclination is down, it will dive. If it is held level, it will hold its depth in a straight path and offer little resistance. This is the proof of the theory I tried to use with my twelve-foot glider on the bank of the river. It is the principle by which all aeroplanes fly—by which gliders and boys' kites, and paper darts, and birds remain airborne. All the other things connected with flight are subsidiary, not one of them is comparable in importance to the fact that a piece of board forced through either water or air exerts lift if placed at a positive angle to it.

In the case of an aircraft, we recognise the flat piece of board as the wing. The engine drags it through the air, and lift is produced which equals, or exceeds the force of gravity pulling it down. The other parts of the aeroplane are afterthoughts—the fuselage to house the engine and the pilot, and the tail unit to exercise directional control and contribute to stability.

At this point, a big question no doubt arises. How does a glider fly if there is no force to pull its wing through the air? The answer, of course, is that it always "flies downhill," an assertion which may appear to be nonsense in view of the story told in the first chapter. Yet every inch of the journey of 110 miles from Dunstable to Cromer was made "downhill." But it was downhill only in relation to the air flowing over the wings, and not in relation to the ground itself. The air was rising, so while the nose of the glider was always pointing slightly towards the ground, the aircraft itself was carried upwards on the rising air. The glider which is flying in a dead calm is in the same position as a bicycle free-wheeling downhill. It acquires its forward movement through the force of gravity—a movement which also provides the flow of air over the wings, which in turn provides sufficient lift to produce a gentle descent.

The Shape of the Wing

Now use of the term "a flat piece of board" fails as a complete description of the wing of a modern aircraft. Whether one is speaking in terms of a jet-propelled fighter or an elementary training glider, the shape of the wing is definitely not flat. Its top surface has a generous curve. This is a modification to the flat surface and is of importance. Expressed in figures, it gives the wing something like three times as much lift.

For many hundreds of years man clung to the "flat surface" idea, which demonstrates how unobservant he was. It was within the capacity of even prehistoric man to observe that the gulls soaring over his native cliff had wings which were curved. It is difficult to understand how, with this example in front of him, man was so slow to realise that the curvature was put there for a reason. If he had had the gumption to take the hint, repeated every minute of the day from every cliff-top in the land, the conquest of the air might have been advanced by hundreds of years. William the Conqueror and his friends had all the materials with which to build a replica of a seagull or of a modern glider. For this reason, understanding of the problems of flight depend upon an appreciation of why the top surface of a wing is curved.

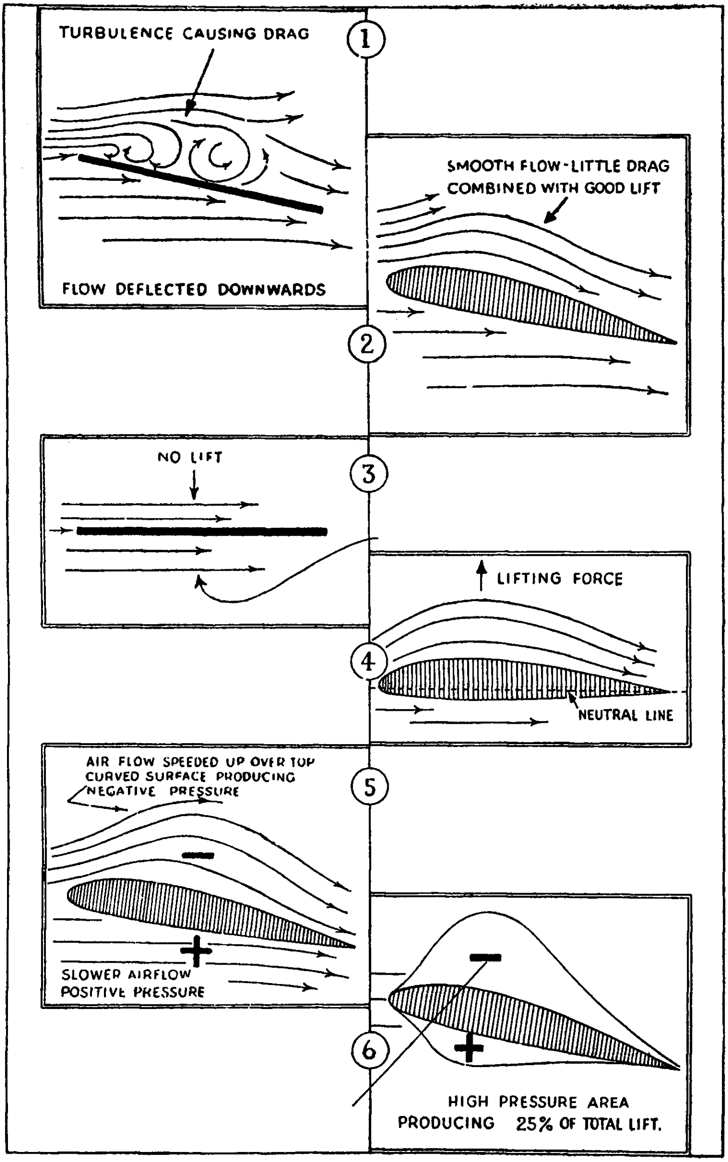
Figs. 1 and 2 show the shape of an airstream passing over the two different classes of airfoil. In both cases the airstream is divided, but as will be seen from Fig. 1, the top half flows over the edge of the flat board and forms eddies all the way down its upper surface. The other half strikes the under surface and continues a more or less even flow until it rejoins the distorted upper stream behind the trailing edge. It is the bottom half which provides the lifting force.

In Fig. 2, which shows the shape of a modern wing section, the area in which the eddies form has been filled in. The result is that the air flows smoothly along both surfaces, joining up again as before at the trailing edge. We have, in other words, disposed of the eddies.

The effect of what might seem at first sight to be only a minor improvement is dramatic. The lift is increased, the resistance to the air (called drag) is reduced, and, lastly, it is found that when this airfoil is lying parallel to the airstream it still continues to provide lift. Indeed, a wing of this section can actually be turned two or three degrees downwards before its lifting qualities disappear. Figs. 3 and 4 show the difference between the two wings diagrammatically.

The reasons why it should produce these outstanding advantages are explained in Figs. 5 and 6. As the airstream is divided by the leading edge, the lower portion is slowed up by friction with the underside of the wing. An area of high pressure is then created.

The other half, flowing over the top surface, will be



FIGS. 1-6. Diagrams showing effect of air stream on airfoils under differing conditions.

accelerated, and this creates an area of low pressure. The suction effect of the low pressure exerts a lifting force three times as powerful as the push from the high pressure on the opposite side. This is shown diagrammatically in Fig. 6.

A little thought about these positive and negative pressures will suggest that still another train of events will be set in motion. The compressed air on the lower surface will seek to fill up the partial vacuum above the upper surface. The effect is a circulation of air from the bottom to the top of the wing. This circular flow spirals outwards, and until it skids off into space at the wing tip, as shown in Fig. 7. Under certain critical conditions, the vortex which streams from the tip becomes visible as a vapour trail.

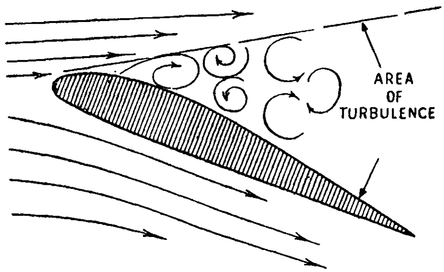


FIG. 7. The cause of stalling. When the airfoil is inclined at too steep an angle, the flow over the surface breaks down and causes complete loss of lift.

Now there are reservations which must be made concerning the performance of any section of wing. We have been speaking of it only in terms of small angles to the direction of the airstream. If the angle, known as the angle of attack is increased to more than 18 degrees, which is the equivalent of a slope of about 1 in 6, the best-designed wing will "stall." That is to say, the lift which it exerts will suddenly be cut off, and cut off dramatically like the snapping of an electric light switch.

What has happened is shown in Fig. 7. The smooth airflow over the top surface has suddenly broken down. Where a second before there had been an area of powerful suction there are now only swirling eddies and miniature whirlpools. These exert no lift and the wing, together with everything attached to it, falls out of control.

Exactly the same effect can be achieved if the weight of the wing, plus the weight of the aircraft, is substantially increased without a corresponding increase in the speed of the air flowing over it. The smooth flow is broken, and the whole thing collapses like a man on a step-ladder which has been knocked from under his feet. Every wing has its own stalling speed, dependent on its design, the load it is carrying, and the speed of the air over its surfaces.

From the pilot's point of view, a stall is to be avoided if the aircraft is anywhere near the ground. I have stalled a fighter and found that I have needed 3,000 feet to recover. Gliders will recover in much less—a few score of feet, and light training powercraft will be under full control again after less than 1,000 feet. At a conversion course from biplanes to monoplanes, I once had to take up a fighter-type of aircraft and stall it in every possible position. The first exercise consisted of a simple stall, created by closing the throttle and waiting until the speed had dropped so that it was insufficient to maintain the smooth airflow over the wings. The first sign was a strange juddering of the tail plane—as though a heavy vibration had been set up. The next instant, the left wing dropped like a stone, the nose went down, and I found myself in a spin. Later on, the same effect was produced at high speed by making an exceptionally violent turn. Without going into technicalities, it is sufficient to say that in one instant I was in the normal attitude of a turn, and the next I was on my back with the world apparently spinning about me and my stomach trying to move up into my throat. At this stage, no more need be implied than that a wing in a stalled position is useless as well as dangerous.

THE CONTROL SURFACES

We have now established a working knowledge of the principal component of an aircraft. The next consideration is to see how its qualities are employed. If we did not know better we might, for instance, argue that all we have to do now is to build a wing, sit on the top of it, and launch ourselves into space. There cannot be a boy over the age of ten who couldn't forecast the result. He would scarcely need telling that a wing by itself is inherently unstable—that it is not like an arrow, which has a natural tendency to continue on the path down which it is launched.

This natural instability has to be controlled before its powers for lift can be used with safety. It is here that the

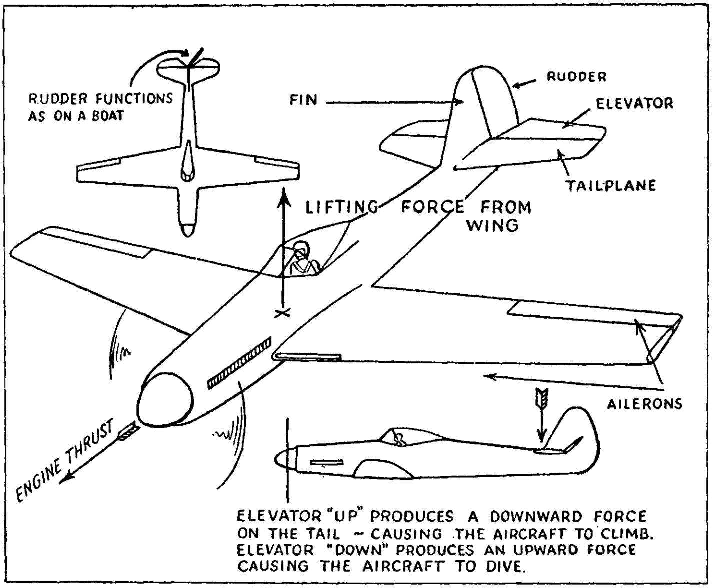


FIG. 8. The flying controls of an aircraft

fuselage and the tail unit play their parts. The fuselage not only provides a space for the pilot, but a rigid anchorage for the wings, while at its after end it offers a mounting in a most advantageous position for the elevators and rudder.

Fig. 8 shows the outline of a typical monoplane. As the engine drives it forward, the wings exert a lifting force in the direction of the arrow. They have no other function. If the aircraft is to be controlled . . . to be made to climb, or dive, or turn, it must be guided by some force extraneous to the wings themselves. This is where the tail unit plays its part. It consists of four distinct components:

1. The fin, a fixed vertical surface which, like the feathers of a dart, maintains the aircraft along a true path of flight, imparting the property known as directional stability.
2. The rudder, which by turning to right or left will yaw the aircraft in exactly the same way as the rudder of a ship.
3. The tailplane, a fixed surface, once again similar to the feathers of a dart, maintaining the aircraft at the correct angle to the path of flight.
4. The elevators, which will raise or lower the tail at the will of the pilot, causing the aircraft to dive or climb as desired.

The manner in which the movable surfaces do their work is illustrated in Figs. 9 and 10. It will be seen that the air-

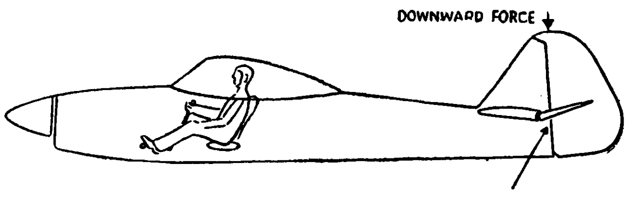


FIG. 9. The use of the elevators for climbing or diving. Backward movement of the control column hinges elevator up, causing aircraft to climb and vice-versa.

stream, striking one side of the rudder forces the tail round, causing the aircraft to turn on a new course.

Equally, it is clear that, when the elevators are depressed, they will force the tail upwards and cause the aircraft to dive. Alternatively, they will force the tail down when they are moved in the opposite direction, and so put the aircraft into a climbing attitude.

If Fig. 10 is referred to once again, it will be seen that a fifth surface, hitherto not mentioned, is situated on the wings themselves. These are hinged panels which are generally

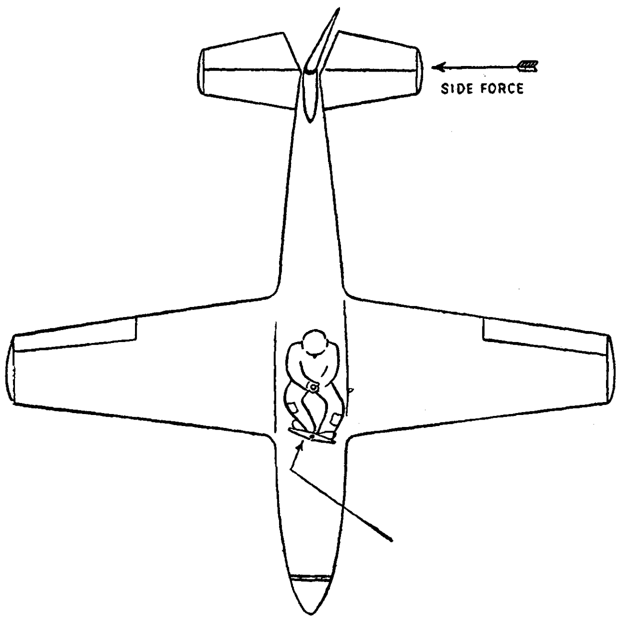


FIG. 10. Actuation of rudder. When the rudder bar is moved to the left, as shown, the rudder moves in the same direction, causing the aircraft to turn to the left.

placed at the outer end of the wings, and are known as ailerons. In level flight, they lie in the same plane, but should a gust give the aircraft a cant, the aileron on the lower wing can be depressed so as to give that side greater lift and so restore the aircraft to level flight. Simultaneously, the process is assisted by raising the aileron on the upper wing, so forcing this down and accelerating the return to the normal attitude (see Fig. 11).

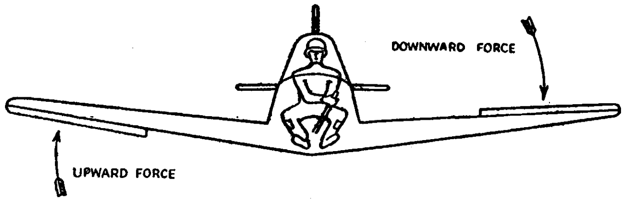


Fig. 11. The use of ailerons for lateral control. When the control column is moved to the pilot's left, as shown, the ailerons are actuated causing the aircraft to roll to the left.

Each of the three movable surfaces—the rudder, the elevators, and the ailerons—is connected to the pilot's cockpit by either cables or rods. The last two are coupled to a stick between the pilot's knees. When the stick is held central, both elevators and ailerons are in a neutral position. When it is pulled back or pushed forwards, the elevators only are affected, and similarly when it is moved to one side or the other, the ailerons move. By pulling back on the stick, and moving it over to the left at the same time, the aircraft will climb and will begin to roll over to the left. It will, in fact, begin what is known as an upward roll. An infinite number of combinations are possible.

The third control—the rudder—is conveniently operated by a bar at the pilot's feet. It functions in a commonsense manner, in that a push to the left will yaw the aircraft to the left, and vice-versa. This completes the list of controls necessary for the guidance of the wing, upon which, basically, flight depends.

DESIGN

When the Air Ministry or the Admiralty want a new design of aeroplane, they issue a specification. They hand over to the manufacturer a list of things of which the aircraft must be capable. The most important are the weight it will have to carry, the speed at which it will have to fly, and the rate at which it must climb.

These three qualities are intimately connected with the shape of the flying surfaces which I have already described. It will be remembered that so far I have said nothing about the design of a wing except that its upper surface must be curved. The degree to which it is curved, its breadth (known as the chord), and its span, all have a profound effect on its performance.

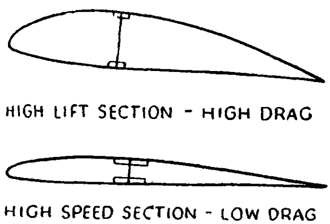


FIG. 12. Typical high-lift and high-speed wing sections

A thick wing will produce more lift for a given speed than a thin wing. That is why weight carriers like bombers have wings of a deep section. At the same time, it is obvious that a thick wing offers a very big resistance to the air. For this reason, it is almost impossible to make bombers fly as fast as fighters. The fighters, whose most important quality is to fly fast rather than lift a big weight, have wings of a very thin section. These are known as high-speed sections, as opposed to high-lift sections, and diagrammatically they are shown in Fig. 12.

A glider offers different problems again. What is needed here is a wing which offers very little resistance to the air, and at the same time produces very high lift. The qualities are incompatible, and the result is a compromise. A typical glider airfoil is illustrated in Fig. 13. In this wing, a forward speed of only 35 m.p.h. will be required to support the weight it will have to carry, and at this speed its drag (or resistance to the air) will be at its practical minimum. Unfortunately, the same wing cannot be anything like so efficient if the speed of the glider is increased to, say 70 m.p.h., by putting down the nose. The practical effect of it is seen in the relative sinking speeds of the aircraft at the two speeds I have quoted. At 35 m.p.h. the rate of sink will be about 2½ feet per second at the best gliding angle. At 70 m.p.h. the sink should, therefore, be 5 feet per second—because the speed has been exactly doubled. It is actually about 7 feet per second. At the higher speed, the aircraft would be more efficient with a higher speed wing section, creating less drag. Unfortunately, it is impracticable to change wings in mid air, and therefore every aircraft, whether a glider weighing 400 lbs., or a bomber weighing 40,000 lbs., has its best speed. That is why the wing of an aircraft is always designed for the particular job in view.

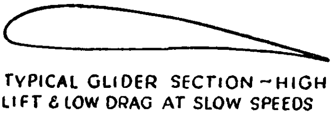


FIG. 13. Typical glider wing section, giving high lift and low drag at slow speeds

OTHER PROBLEMS OF GLIDER CONSTRUCTION

Plate 9 is a photograph of a modern high-efficiency glider. The first thing which appeals to the eye is its lovely shape—or, in terms of the air, its streamline. The fuselage is gently rounded and highly polished. The wings are faired into its sides, while even the cockpit blends into the nose as though it were part of it.

The designer of this aircraft has done everything he can to assure that the flow of air round his machine shall be smooth and easy. He has, in other words, reduced the drag to an absolute minimum. He has done this because drag is the greatest single enemy of sailplanes. There is no engine to overcome its resistance. The only power of which he can make use is the power of gravity when the aircraft is flying downhill. It is this which, like a motor car on a slope, gives it its forward movement, which in turn provides the airflow over the wings to keep the craft airborne.

Whereas a fighter with its engine switched off requires to be pointed steeply at the earth if it is to maintain controlled flight, this glider will continue to fly with all the necessary speed when the nose is only just below the level of the horizon.

One day, when making practice forced-landings in a fighter, I had a nice demonstration of this. As soon as the engine was throttled back, and the machine became a glider for all practical purposes, I had to push down the nose to a steep angle to maintain the safety speed of 90 m.p.h. Even then, the ground came up towards me with remarkable rapidity. I was actually losing height at about 20 feet per second, as compared with the 2½ feet per second which would have been possible in a sailplane.

The quality which gives a sailplane so flat an angle of glide is the absence of drag, and the absence of drag is attained by complete streamline. The quality can either be expressed in terms of height lost per second, or in distance flown for height lost. The former has already been mentioned—2½ feet per second. The latter, known as the gliding ratio, is about 25 to 1—a loss of 1 foot of height for every 25 feet flown. The comparative performances of various types of glider, from the most efficient to less efficient training types, are shown in Fig. 14, and for comparison I have included the gliding angle of a fighter to show how, in this particular respect, it is the least efficient aircraft of all. The drag created by the slowly revolving propeller, the engine radiators, the undercarriage (if lowered), the cannons protruding from the wings, the wireless aerial, the cockpit hood, and the rough surface of the fuselage itself, all add up to a tremendous negative force. The result is that from a thousand feet, the distance which the aircraft can glide in still air is a mere 1¼ miles. The more efficient glider, in spite of its lower speed, travels nearly four miles from the same height. It remains airborne for about seven minutes, whereas the fighter is on the ground in fifty seconds.

The Float of a Glider

It is obvious that the narrow angle of glide possessed by a sailplane is a tremendous advantage under all conditions except when landing. It can then be an embarrassment. The machine refuses to "sit down" and goes floating across the chosen field towards any obstruction at its further end. Before devices were perfected to deal with this situation, I remember watching the efforts of a pilot who was trying to get into a comparatively small field which, under present conditions, would be easy.

He first beat up and down the stone wall along its windward boundary, at each turn the wing tip coming nearer to the ground as he made his turns. Finally, it was impossible to lose more height before turning into wind, for on his last turn the wing tip had not been half a dozen feet above the wall. Yet even then, as he skated six or seven feet over the grass field, he was losing height so slowly that it was obvious he would hit the hedge at its further side. No doubt the air above the field was gently rising, reducing his rate of sink to

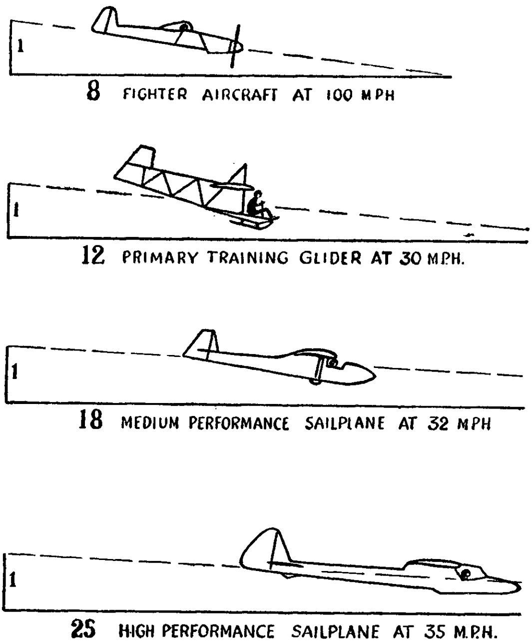


FIG. 14. Comparative performances of gliders and fighter aircraft

a few inches per second. Finally, the aircraft finished with its nose buried in one of the thorniest bushes in the district. The pilot's face was in the middle of it—and required repairs to the extent of many pieces of sticking plaster.

Today, the wing would have been fitted with one or two devices which can be operated from the cockpit to destroy the "float." The simplest is known as "spoilers," and reference to (Fig. 15) shows that they are slats about three feet long and three inches wide which can be raised from the top surface of the wing. Their effect is to destroy the smooth flow of air over that part of the surface, with the result that the lift is decreased and the aircraft sinks.

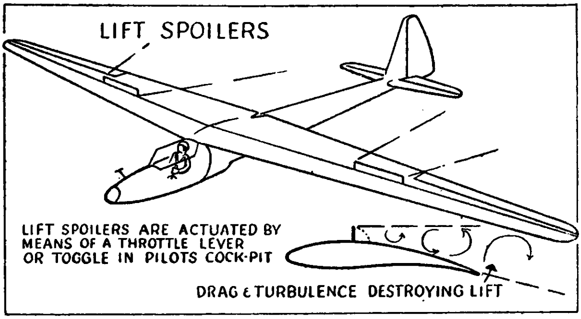


FIG. 15. Lift spoilers

Alternatively, flaps can be fitted. These are of two types, and both are commonly fitted to power craft as well as sailplanes. The effect of each is approximately the same. In one type, a section of the trailing edge of the wing is split, as in (Fig. 16 above), and a panel comes down, first to increase the lift and then to offer serious resistance to the air. In the other type (Fig. 16 below) a complete section of the trailing edge is bent downwards to give the same lift and drag effect. The increased drag amounts to a braking effect which slows up the machine and makes it necessary for the pilot to depress the nose still further in order to maintain flying speed. The net result is that the gliding angle is reduced from about 25 to 1 to 12 to 1.

WING LOADING AND SPEED

We have now almost reached the stage when we can go to our nearest gliding club and apply for membership as a pupil. But it is a pity to spoil the ship for the sake of a ha'porth of tar, and begin our flying career short of knowledge which we may find useful. For this reason, I think that two other things which have a profound effect on the behaviour of all heavier-than-air machines should not be overlooked.

The first concerns the weight of a glider in relation to its speed. It must be obvious that the greater its weight, the faster it will run "downhill." At the same time, it will be equally clear that if the weight is doubled, while the size of the wings remain the same, it will not be able to fly so slowly. A faster airflow over the wings will be essential to support the increased weight.

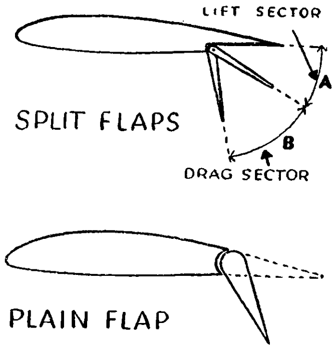


FIG. 16. (*Above*) Split flaps. When the flap is depressed through the range marked "A" the lift is increased; through range "B" the lift remains the same, but the drag is greatly increased. (*Below*) Plain flap

Now the weight characteristics of an aircraft are expressed in the number of pounds which every square foot of the wing surface has to support. This is known as the "wing loading." A heavy bomber or a fast fighter may be loaded to 50 lbs. for every square foot of its wing surface. A glider, on the other hand, is rarely loaded to more than 4 lbs. Yet even this is heavy compared with the loading of a small bird, which is only about a quarter of a pound. The lightest loaded creature which flies is probably a gnat, and its wing loading is approximately one thousandth of that of a glider.

These figures are the explanation of why one class of aircraft requires a wind speed of at least 100 m.p.h. over its wings to support it, while another is equally efficient at 30 m.p.h. The glide of a gnat (if gnats do glide) would probably not be faster than 3 m.p.h.

Stability

Now we come to the last of my points, and it is necessary to go back to the beginning of this chapter to study it. It is bound up with the original statement that the wing of an aircraft has no inherent stability of its own. I have already explained how three movable control surfaces have been added to bring it to heel. But these by themselves are not sufficient. Two other fixed surfaces have already been mentioned—the tail fin, and the tail plane. If the pilot was without them, he would continually be forced to move the elevators and the rudder to prevent the wing taking charge.

Now even pilots dislike doing unnecessary work, and so great efforts have been made to give the aircraft automatic stability. It is here that these two flying surfaces play their part. The tail plane, in addition to supporting the weight of the after-end of the fuselage, has a stabilising effect. If, for instance, the aircraft begins to dive, the tail rises, and the airstream will then play upon the top surface of the tail plane, tending to force it down again. Similarly, if the nose rises, the tail will drop, and the airstream will now strike the underside of the tail plane and tend to force it up again. Hence, it may be said that the tail plane gives fore and aft stability.

The fin, to which the rudder is hinged (see Fig. 8) has the same effect in a turning direction. Should the nose yaw to the left, the air stream will strike the right side of the fin and push it back. These two surfaces look after stability in all directions except in a rolling plane. For the latter, we have the third and last device for giving automatic stability. This is not anything additional which is attached to the aircraft, but is achieved through setting the wings at a slight upward angle to the fuselage. It is called "dihedral." In practice, it is found that an angle of three or four degrees is sufficient to achieve the necessary effect.

Were the wings not given such an angle, there would be a tendency for the aircraft to roll on to its back every time it was hit by a gust. As it is, it resumes its normal attitude without any action on the part of the pilot. I have often flown an aeroplane without hands or feet touching the controls, and watched how the aircraft gradually comes back to an even keel of its own accord. When I have been teaching pupils to fly, it has often been necessary to tell them to relax and give the aeroplane a chance to fly itself. Their continuous corrections for every little gust were quite unnecessary. It is only something really violent which demands assistance from the pilot.

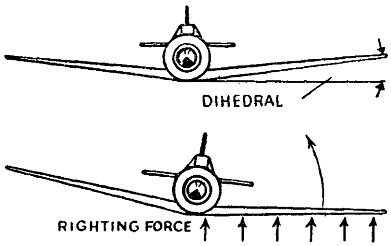


FIG. 17. The effect of dihedral angle in giving lateral stability.

Fig 17 shows how "dihedral" works. A gust has struck the right-hand wing, thereby pushing the opposite wing down. The latter is now directly facing into the air stream, and will therefore be exerting more lift, while the uppermost wing is now at an increased angle to the airstream and will be consequently exerting less lift. The combined effect will be to restore the aircraft to its original position.

MAKING A MODEL GLIDER

A simple model glider which can be made in less than five minutes will enable anyone to prove many of the foregoing points for themselves. While it has no fin in the accepted form, the "dihedral" angle given to the tail plane takes its place and provides stability. It is the best model I have seen, and if you take it with you on your first visit to a gliding club, you will find that you can soar it in competition with full-sized aircraft.

Fig. 18 shows how it is made. The first, and only requirement, is a piece of good quality note paper measuring about 10 inches by 8 inches. The more "crisp" the feeling of the paper the better. Heavy and "soggy" paper is a disadvantage.

The first drawing shows how the paper is folded nine times along its long edge. If there is a twist in the completed folds, draw them over the sharp edge of a desk.

Now fold the sheet as shown in the second drawing, and cut out the pattern as in No. 3. With the outline of the model complete, but still folded wing to wing, bend down the tail plane tabs on each side (No. 4). Open the model out, and fold up the last quarter inch of the wing tips (No. 5). Bend the leading edge forward at the centre for 1 inch of its length (see also No. 5). This stiffens the wing and gives it a dihedral angle.

Next, as in No. 6, put the rib creases in the underside of the wings—three or four of them to each side. The creases give the wings stiffness and camber. This last operation requires a little care, and it is done as follows. Hold the model with the right hand, upside down and facing to the right. Then with the thumb-nail against the forefinger of the left hand, "draw" the creases one after the other on the underside of the wing (i.e., on the underside of the model, but on the top of the wing as it appears to you). Now hold the model the right way up and again facing to the right. This time, make the creases on the underside of the wing nearest to you (on the side away from you this time) with the middle finger nail of the left hand against the ball of its thumb. Lastly, a small crease at the centre of the "fan" tail will complete the model, This is also shewn in the sixth drawing.

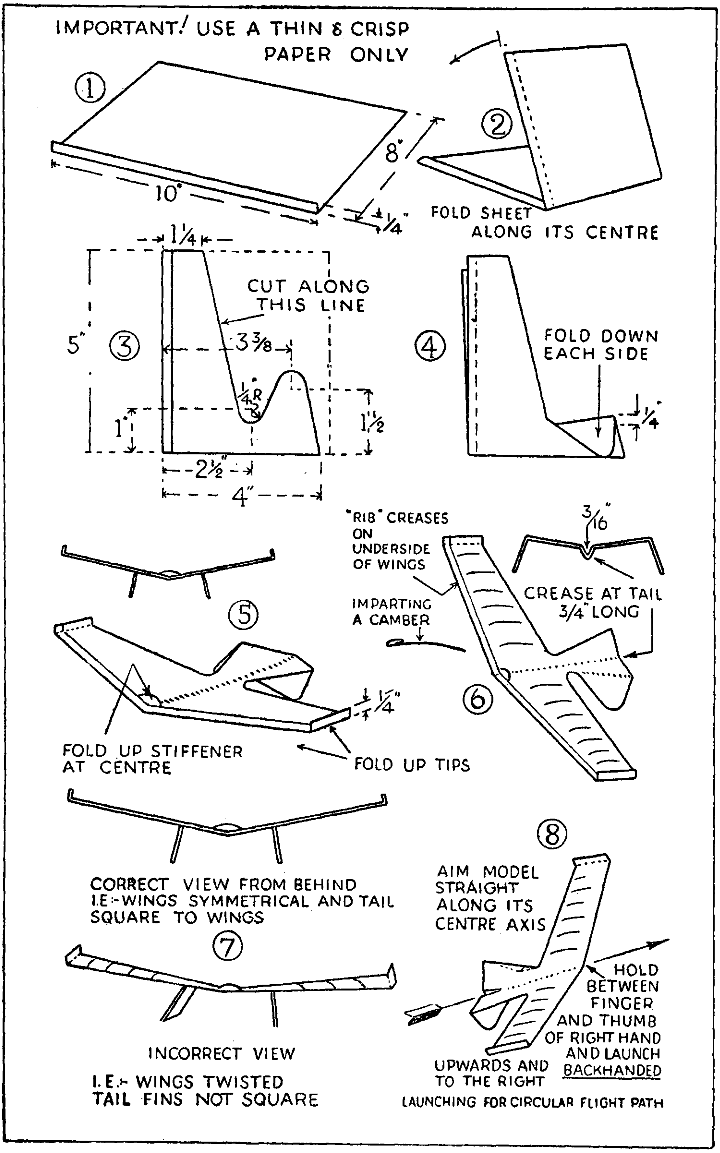


FIG. 18. How to make a model glider

Flying the Model

Before air testing, the model should be "rigged" for flight. Hold it so that you can view it from behind, and remove any excessive camber from the wings. At the same time, ensure that the fuselage or wings are not twisted. The drawing marked No. 7 shows how it should appear.

The technique of flying the glider comes with practice. The first test should be made indoors, and should consist of a straight glide. Hold the "fan" tail between the finger and thumb, and launch the model firmly but smoothly on a downward path. If the rigging is correct, it will continue along this path in a long, straight glide.

If it banks, a little thought will show you that one wing or the other requires a very slight twist. If the model dives, bend the elevators slightly upwards. If it stalls, that is to say, if its path is a series of curves, at the end of which the nose is at its highest, then the elevators need bending down.

After establishing the straight glide, you can develop the model's potentialities to the full. Hold it in the attitude shown in the last drawing (No. 8), but instead of grasping it at the tail, hold it by the nose (still between the forefinger and thumb of the right hand). The launch is made with a firm, back-handed flip to an imaginary point about 10 feet high and to the right. This will result in a steady circular flight round the room and back to the point of launch, where it may be caught in the hand. Only a little practice is needed to achieve this.

Looping can be effected by a similar launch, except that its direction should be forward and downward. If the room is high enough, the excess speed of the dive will result in a subsequent climb and a neat loop.

On a calm day, it can be flown outside from the crest of a hill, and if a gentle breeze is blowing on to its face, you will be able to demonstrate the first principles of ridge soaring.

CHAPTER THREE

THE FIRST DAY AT A GLIDING CLUB

We join a gliding club, meet our fellow-members, and have a surprise flight in a two-seater. A memorable day which ends with our first lesson.

Armed with the knowledge of how aircraft fly, we can climb the hill leading to the headquarters of the gliding club with confidence. It is a steep hill, and the road twists and turns through the trees, crawling round hairpin bends, and struggling upwards to the blue line of the sky, where the clouds drive downwind like ships under sail. Round the last bend the trees break on the crest like a green wave, and we are suddenly in a land of rolling heather, and crisp, clean winds. In the shadow of the last tree is a grey farmhouse, its low buildings forming three sides of a square. For a farmhouse, it shows signs of unusual activity—sweatered men and trousered girls engrossed in jobs which have nothing to do with farming. One of them is starting up what appears to be an old taxi, another is frankly enjoying a sun-bath in the cobbled yard, while there is a glimpse of a third whose occupation is connected with the wing of a glider laid between two trestles in the shadows of the open barn door.

As a new member, we seek out the secretary, and discover him with pencil and paper and pot of beer in what was probably the parlour of the farmhouse, and is now the bar. He's on the bar-tender's side of the counter, and if one didn't know better, we might mistake him for the retired Captain of a sailing ship entertaining some of the tougher members of his former command. In fact, a conference is in progress between the club's honorary instructors, and the list of pupils is being made out for the day.

There are two other new members present, and within half a minute we are being introduced. One of them is a boy who doesn't look older than fifteen. He's riding on a wave of enthusiasm—not merely because he's to have his first flying lesson this morning, but because he's accepted by the older men as one of themselves.

The other pupil is much older . . . perhaps ten years. He has a shock of fair hair, a friendly blue eye, and shy, quiet manners. We novitiates occupy ourselves by drinking a lemon squash and a couple of half pints until the tough-looking band of instructors have made out their lists. Then the secretary and the Chief Flying Instructor come over, and we sit in the sun which streams through the open window and swear that we have paid our subscriptions and are ready to start flying.

"Have you done any gliding before," asks the C.F.I.?

The youngest member shakes his head and admits that he doesn't know a thing about it.

"Good—you'll be easy to teach" is the rejoinder. "The fellows we're afraid of are those who've just got their 'A' licences in power-craft and think they know everything." He turns towards the fair-haired man. "What about you," he says.

"Not guilty . . . never been near a glider in my life."

The secretary looks at a paper, which is his application form, and says, "I thought you were a power pilot?"

"Yes," he replies in a hesitating voice, "but I'm anxious to start from scratch . . . all this is new to me."

"You were flying Lancasters, weren't you?" says the Secretary.

He admits that he was . . . some while ago. When pressed, he acknowledges to thirty-seven operational trips over Germany, and says again that he wants to start at the beginning.

When the Chief Flying Instructor has the Secretary to himself later in the morning he comments: "That fair-haired chap should make a good soaring pilot . . . he's got guts and intelligence." We happen to overhear the remark, and make a resolution privately to ourselves . . . "however clever we are on the theory of flight, we will never 'shoot a line,' and we will listen and learn, just like the man who's made thirty-seven trips over Germany."

We start learning immediately. The secretary takes us through the back of the farmhouse and out on to the great tableland of heather which stretches ahead as far as the eye can see, although over on our left it ends abruptly in a cliff-like edge which drops six hundred feet into the plain. The ex-bomber pilot is with us and whistles through his teeth when he sees it. "I'll bet the air is rough over the top of that," he says.

"You'll soon find out," replies our guide. "As a matter of fact, it's usually smoother than it looks." He turned his eyes in our direction and asks, "You know how the hill works "

We shake our heads, remembering our resolution.

"There's an updraught over it . . . probably 10 feet a second in today's wind. The breeze is striking the face of the cliffs, and because it can't blow through them, it is bent upwards over the top. On some days the air keeps on going up for a thousand feet . . . on others it straightens out again after only a hundred feet."

"What's it doing today?" asks the bomber pilot? His companion looks at him as though he weren't sure whether the new pupil doesn't already know the answer. But there is no guile in the ex-R.A.F. man's face. "Flying Lancs. doesn't teach you everything," he says.

"I should say the ceiling was a thousand feet," replies the C.F.I. "It usually is when the sun shines and there's plenty of cumulus cloud in the sky. You'll learn why later."

As he finishes speaking, there's a cough from an engine further along the cliff-top. It comes from the launching winch—a big, square-built juggernaut which once had a job in London controlling a barrage balloon. By the time we reach it, the engine is warmed up and, looking away from the cliff edge, our eyes follow a thin steel cable across the level top of the moor, until in the ultimate distance, nearly a thousand yards away, we see a glint of light on the wings of a sailplane.

The first launch of the day is imminent. Over the winch-driver's ears is a pair of telephones, and through them a voice is saying—"Take up the slack . . ." The driver touches a lever, and the drum holding the cable makes a few revolutions. Then the voice comes again, "Slow ahead . . . " and then, quickly, . . . "full speed!"

The throttle is opened, the engine hums, and the steel wire suddenly bursts into a high, singing swish as it is reeled up across the heather at 30 miles an hour. Far across the moor, we see that the sailplane has moved. In another second it seems to leap into the air, so steeply that we see the whole of the underside of the wings and the lower part of the fuselage. Never, in our experience of watching aeroplanes, have we seen so steep a climb.

Our companion turns to us and says, "You see the idea, it's the same principle as a kite!"

We nod, and watch fascinated. There is a new sound now . . . a clear, trilling sound like the note of a church organ. It is a noise with which we are to grow familiar—the rush of air over the hull and wings of a perfectly-designed sailplane. It is the thing, which perhaps more than anything else grips the imagination of the bomber pilot, who for so long has heard only the harsh roar of aero-engines.

We strain our necks upwards as the glider climbs—until the steel wire runs almost vertically over our heads. Then, without warning, the wire collapses, twists into a hundred coils, and comes streaming towards the earth like a long snake. Up in the cockpit, the pilot has pulled a ring on his dashboard, and the jaws of a hook have opened to release the cable.

For a moment, the sailplane holds its course so that it flies out over the edge of the cliff, seven hundred feet up. Then it turns, to follow the line of the ridge, and even from here we can see that it is climbing.

Other sailplanes are being ranged in the distance for their turn on the winch. Parties of toiling figures, like chain gangs, drag them from the hangar at the southern end of the slope. One or two are being hauled by motor car, and we recognise the ex-taxi with a two-seater in tow. Further across the moor, towards the northern end of the cliff, there is another group of figures, with two or three crude-looking gliders, a couple of motor cars, and a second winch. They are the training party—instructors and their pupils who are being given first flying lessons. As we watch them, a bell tinkles on the nearby winch car, and its driver picks up the receivers which he has taken off. In another minute he is coming over to us and addresses our companion.

"The C.F.I. has just rung up," he says, "and wants to know if you'll give the two-seater a test flight?"

The club's secretary nods, and we hold our breath as he turns to us.

"Would you like to come up?"

For once there is no doubt about the correct answer.

"Put the safety straps over your shoulders . . . top right first, then bottom left, bottom right, and top left . . . good . . . now for the safety pin . . . push it right home . . ."

We are sitting beside the pilot in a cockpit in which there is only just room for the two of us, side by side. Now we are

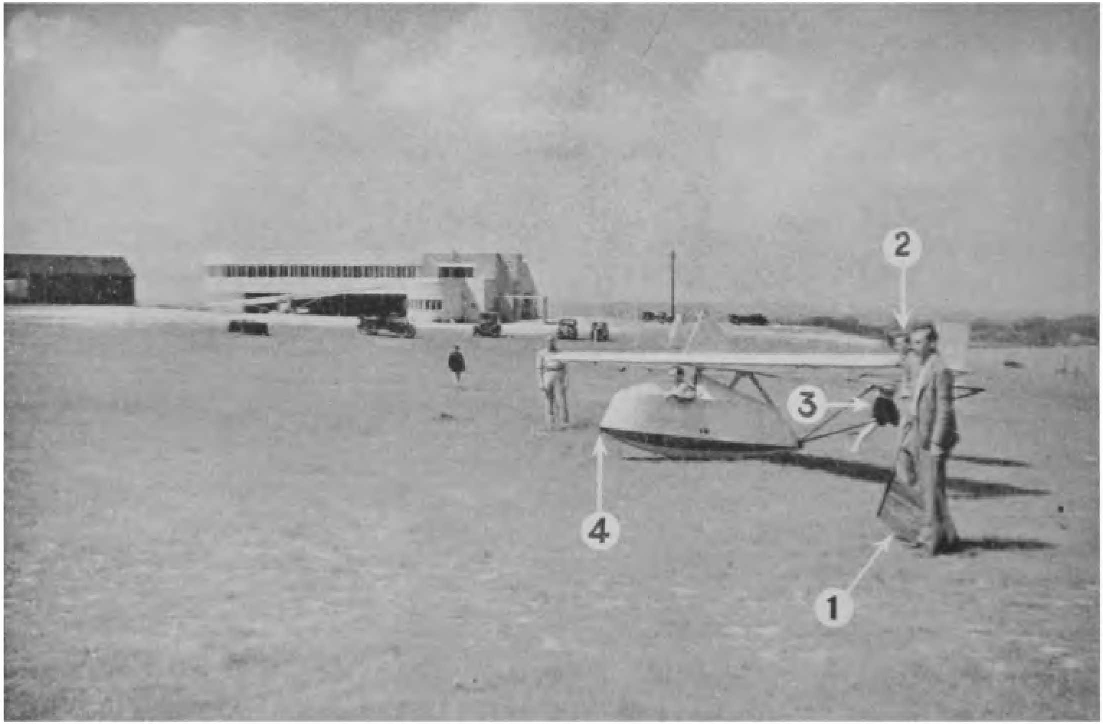


PLATE 6. The launching crew: 1, The instructor with his signalling flags; 2, The man on the wing tip; 3, The man holding back; 4, The point of attachment for the winch cable.

PLATE 7. The Falcon III, the most famous of all two-seaters. Dual control is fitted and many pupils have enjoyed their first experience of thermal soaring in aircraft of this mark.

at the other end of the launching cable, and far out on the horizon, where the edge of the cliff makes a clear line against the sky, we see the winch car by which we had stood. The cable has just been hooked on to the nose of the machine, and a fellow-member of the club, who is crouching beside our wing-tip, is speaking into a field telephone. Another man is holding up the opposite wing tip, for the aircraft rests on a single skid, and requires support to keep the wings level until we have reached flying speed. It will mean that he will run forward with us as we move off—but the pilot says that in this wind we shall be off the ground in a few yards.

The cable tightens . . . an urgent instruction is passed over the telephone, and suddenly we are swept forward, bumping over the heather. Looking to one side, we see the wing snatched out the hand of the running helper, and in the same instant the bumps disappear and we have the impression of smooth, swift passage close to the ground, like gliding on ice.

Then, out of the corner of one eye, we see the pilot pull back on the stick. The total movement is not more than an inch, but it has a dramatic effect. We are pressed into the seat, while the skyline disappears and the nose rises until it is pointing at a cloud sailing overhead. The way to see the ground is to lean over the polished wooden panel which forms the side of the cockpit, and when we do this, we see the winch cable as it drops away from us and swings slowly through hundreds of feet of space until it disappears into the little box which is the winch. Beyond the winch, there is the great step in the earth, now appearing as a hideous drop into the shadows of the plain. The wind is full of small treble noises, but they are harmonics to the deep, rich, organ-like note which seems to come from the wing immediately above our heads. The fuselage contributes its voice, too, the small, secret sounds of a wooden ship under sail.

The control stick moves forward again under the hand of the pilot and the sounds ebb like a receding wave as we level off. Looking out once again we see that the winch is almost immediately below, the face of the driver looking like a white watch face against a dark background. Then the pilot sharply pulls the release ring in front of him and the wind sinks to a soft whisper which trills gently on the sub-tones of the deeper, basic voice of the sailplane. Down and down the cable goes curling, piling itself on the dark heather.

"And that's that," remarks the pilot in conversational tones. "You'll find we strike the lift any second."

The aircraft gives us the feeling of being suspended on invisible strings. The nose is pointed slightly down, so that we can see clearly over the bows. In the distance is a smudge of smoky-blue, which is haze above the little town through which we passed on our way into the hills. Between us and the town, the quartered fields spread in endless pattern, and through them the roads wind aimlessly.

This strange feeling of being in peaceful suspension is suddenly shattered by a surge of invisible air which seems to strike under the left wing. As the wing rises under its force, the pilot pushes the stick firmly over to one side to counter it. The sailplane comes back instantly to an even keel, but the tumble and tug and thrust of the air remains.

"We're in the lift," remarks the pilot . . . "and it's good."

He turns to run up along the edge of the cliff, and points to a little instrument on the dashboard. Its needle has moved across from its central position to show that we are climbing at four feet a second. By the time we have come to the end of the cliff where the ground falls into a shallow valley, like the side of a house which has crumbled into decay, the altimeter has risen from 700 to 1,100 feet. We turn and run back over the ridge, seeing the tiny figures moving like ants on the moor. Another sailplane passes fifty yards away, and its pilot raises his hand in greeting. We seem to have reached the limit of height possible, for we are now only just maintaining our altitude.

"We'll go out over the valley and look for a thermal," says the pilot.

Without knowing what a thermal may be, we are aware that our craft is being turned outwards across the plain and away from the hills. The result is that the air becomes perfectly smooth again and at the same time, the needle on the little dial moves to the left, passes the zero mark, and mounts the opposite scale where it shows a rate of sink of three feet per second.

In this way, losing nearly 200 feet every minute, the aircraft flies gently over the sunlit country, and we are really beginning to enjoy the sensation of flying when the pilot interrupts by saying : "No luck—we'll have to cut and run for it."

Then we realise that we are down to 600 feet and that we are far from the ridge where we were launched. On the way back, the glider is losing height steadily, and at one moment it seems as though we are not going to clear the cliff face which comes springing towards us. In fact, of course, there is a good margin—the return was perfectly judged. The moment we cross the edge at a hundred feet, we turn to run along its crest again, this time perilously close. We are back in the wild air, tossing relentlessly, but the important thing is that we are climbing again. The climb continues to the end of the cliff and all the way back for another mile, until we are once again at over a thousand feet

"There should be any number of thermals about," remarks the pilot, and he again turns the aircraft out over the valley—out into the smooth air above the fields.

"We'll try to find one over the village to the left," he says.

This time, the smooth air ends abruptly when we are least expecting it—almost directly over the little huddle of roofs towards which we have been flying. Gusts are playfully buffeting the wings as though we were in a sailing boat meeting the sea outside its harbour.

Immediately the pilot moves his control column, and the aircraft swings into a smooth turn. The turn is continued, and we fly circle after circle. The pilot points to the instrument again, and we see that the sink has given place to a climb of five feet per second.

"This is a thermal," he says, "and it's a good one."

We climb with increasing smoothness at 600 feet every minute, and the pilot explains that a bubble of warm air has collected over the roofs of the village through the sun playing on their tiles, and that it has just broken away like a giant soap bubble and is floating up to the clouds. We are going up with it.

At 3,000 feet we are deep in the shadow of a cloud overhead, and it is clear that if we go on, we shall be sucked into its base.

"Thermals generally flow into clouds," says the pilot, "in fact, that's what makes the clouds—the moisture in the thermal condensing like steam in the colder air."

As we approach the cloud, the speed of our climb increases to ten feet a second, and then suddenly the sight of the world below is snatched away and we are flying in what appears to be a dense fog.

But this is only momentary, for the pilot moves the controls again, and explains that he has stopped circling so that we are to come out of the side of the cloud. Our eventual exit about half a minute later is dramatic, for we appear to fly through a wall, from darkness into intensely bright sunlight. Far below, the purple moorland rolls to the east, and away to the north we see the cliff edge from which we have come—so far away that the big hangar looks no larger than a road-mender's hut.

"We've been drifting down wind at about twenty miles an hour," says the pilot. "Now we've got to get back."

He puts the nose of the sailplane into a slightly steeper glide, so that the air speed rises from 35 to 45 m.p.h. and the song of the wind shrills a higher note. Now we are losing height at about five feet a second, but by the time we reach the landing ground again, we still have over 1,000 feet to spare. As we go down, it becomes noticeably warmer, and we learn that this is no imagination. When we were at 3,500 feet—our highest point—the air was at least fifteen degrees colder than at ground level. For every thousand feet of our climb, the temperature dropped about five degrees.

We swing smoothly over the landing ground, skim the stone wall which marks its boundary, hear the heather rustle for a moment along the hull, and then suddenly we touch the solid earth. It seems to rise up to grip the keel like treacle. In twenty yards we are at a standstill, and the tip of the wing on our side sinks gently until it rests on the ground.

Lunch is an informal affair served under the low roof of one of the farm buildings—and it costs the modest sum of one and six pence, It is here that a great truth which is common to all gliding clubs begins to impress itself upon us. The work is being done by the club members themselves—in this instance aided by wives and girl-friends. The rigging of the aircraft before flying began, the hauling, the pushing, the winch driving, and the instructing were all done by voluntary effort. Unless one works, it is clear that the sooner one gives up gliding the better.

We have a twinge of conscience—and the man sitting next to us, apparently a thought-reader, breaks in on our silence. "Coming to lend a hand this afternoon?"

We nod vigorously.

"Good," he says, "I've put you down with a batch of new pupils, and we'll give you a slide."

"Does that mean I'm going to get a flying lesson?"

The great man nods.

The training glider rests on the ground at the far end of the soaring ridge, and at least 300 yards from where the cliff drops into the valley. Around it are gathered a bunch of new pupils, and a tousle-haired instructor in an old sweater. The instructor is speaking:

"She's not much to look at," he says (reference to Plate 2) shows that this type of glider consists of little more than a wing, a skid on which a bucket-seat is mounted, and a tail unit carried on the end of a boom), "but she flies and she's practically unbreakable."

During the next few minutes we learn the basis of how primary instruction at the club is carried out. But first we are given details about the glider itself. It weighs 220 lbs. and boasts of a gliding angle of 1 in 12—which, we remember, means that it loses one foot of height in every twelve feet advanced in a forward direction—a poor performance compared with the streamlined hulls of the high-efficiency types soaring over the ridge. The instructor adds that this gliding angle is not good enough to allow the machine to soar (save in exceptional conditions), but that after a few lessons each pupil will go up in it to a height of 600 feet, from where he will be able to make a straight glide back on to the moor. It will take about 30 seconds.

"Such a flight will give you your 'A' certificate," he adds, "and the average pupil makes this after ten visits to the club, or a total of thirty launches."

Then he explains what is about to happen. While he is talking, the first pupil takes his place in the bucket seat and starts to fasten his safety harness. The glider, we learn, will be pulled into wind through the heather by the distant winch, whose wire cable has already been stretched out so that the steel ring on the end of it is now ready to be hooked on to the nose of the glider.

"If the winch-driver pulls at his ordinary speed," says the instructor, "the glider will leave the ground—unless the pupil holds the control column forward. But the man on the winch knows that you are pupils, and he's going to treat you gently . . . he'll keep the speed down so that whatever else you do, you'll not fly."

We are told that the glider will remain under control at an air speed as low as 25 m.p.h. As the wind is blowing over the moor today at about 10 m.p.h., the speed of the glider over the ground as it is pulled towards the winch will therefore be less than 15 m.p.h. (it is facing directly into wind), making the airflow over the wings insufficient to lift it.

"The object of the exercise," concludes the instructor, "is to teach you how to use two of the three controls—the ailerons, which will keep your wings parallel to the earth, and the rudder, which will keep you on a straight course."

But even before the pupil is allowed to carry this out, the instructor makes sure that he understands the manner in which the controls work. To do this, he stands by a wing tip and balances the glider on its skid.

"Right," he says, "you're flying straight and level . . . stick central."

The pupil, with a tense expression on his face, holds the control column in a vice-like grip in its central position.

"Let's relax," says the instructor, "you can fly nearly any aircraft which was ever built, including a Spitfire, with two fingers . . . Right, I'm going to put one wing down . . . that's a gust . . . and I want you to make the proper correction with the control column."

Suiting the action to the words, he lowers the wing which he holds in his hand, and the pupil moves the stick over to the opposite side. As he does so, the instructor raises the wing—just as the air would raise it if he was really flying—and because the pupil continues to keep the stick hard over, he likewise continues to lift the wing, until he is holding it high above his head. At this moment, the pupil realises what has happened and slams the stick across to the other side to bring the aircraft back once more on to an even keel.

"Rather over-corrected that time, didn't you," says the instructor with a smile.

The practice is continued for a minute or two, by which time the pupil is picking up his wings and bringing them parallel with the ground whenever the instructor puts on "a gust."

"That's pretty good," says the instructor. "But if you'd been really flying, you would have crashed. Whenever you moved the stick to one side, you pulled it towards you at the same time. That would have pulled up the nose, so that you'd have lost flying speed, stalled, and crashed! Try to keep the lateral movements divorced from fore and aft movement, in other words, keep the stick central."

The pupil looks desperately serious, and tries again. This time he makes the right corrections to the ailerons without either pushing the stick forward or pulling it back at the same time. The instructor turns to the rest of us, and says, "that's just what I want . . . the elevators never moved from their neutral position (see Fig. 19 for elevators when neutral).

The pupil is now ready for his first pull across the level moor. The ring on the cable is slipped over the open hook on the nose (see Fig. 20). The instructor picks up a pair of white flags and begins to move one of them slowly up and down. (See Fig. 21 for the control signals.)

Meantime, another pupil holds up the wing by its tip and is ready to run with it until the glider is moving fast enough to be under aileron control. The winch-driver sees the instructor's flag signal and begins to take up the slack in the cable by slowly revolving the drum of the winch. While this is happening, the instructor calls out to the pupil to hold the stick a little forward of the central position. This is a safety measure, so that should a gust lift the aircraft, the forward position of the elevators will put it down again.

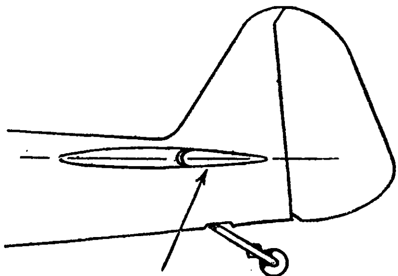


FIG. 19. Elevator neutral

The wire tightens, and the instructor immediately raises his second flag and moves both up and down, from his head to his knees. In the distance, the winch driver sees the new signal and speeds up his motor. The glider moves forward, the pupil on the wing tip runs with it, and in a moment the "slide" is under way.

From where we stand we can see the glider sliding across the heather. We can even see the elevators moving from side to side as the pupil keeps his wings in the level position. Either gusts, or perhaps little hummocks of rougher ground are continually causing one wing to drop. We see the elevator on the low wing go down, giving that side extra lift, and so bringing it up again. Several times the parallel attitude is more than restored, and the opposite wing goes down.

"He's still over-correcting," says the instructor. "It's the fault of most beginners."

Now we see the rudder moving as the glider slews off its course. As it occurs, the instructor says, "correction by the rudder is instinctive, you can't help doing it any more than

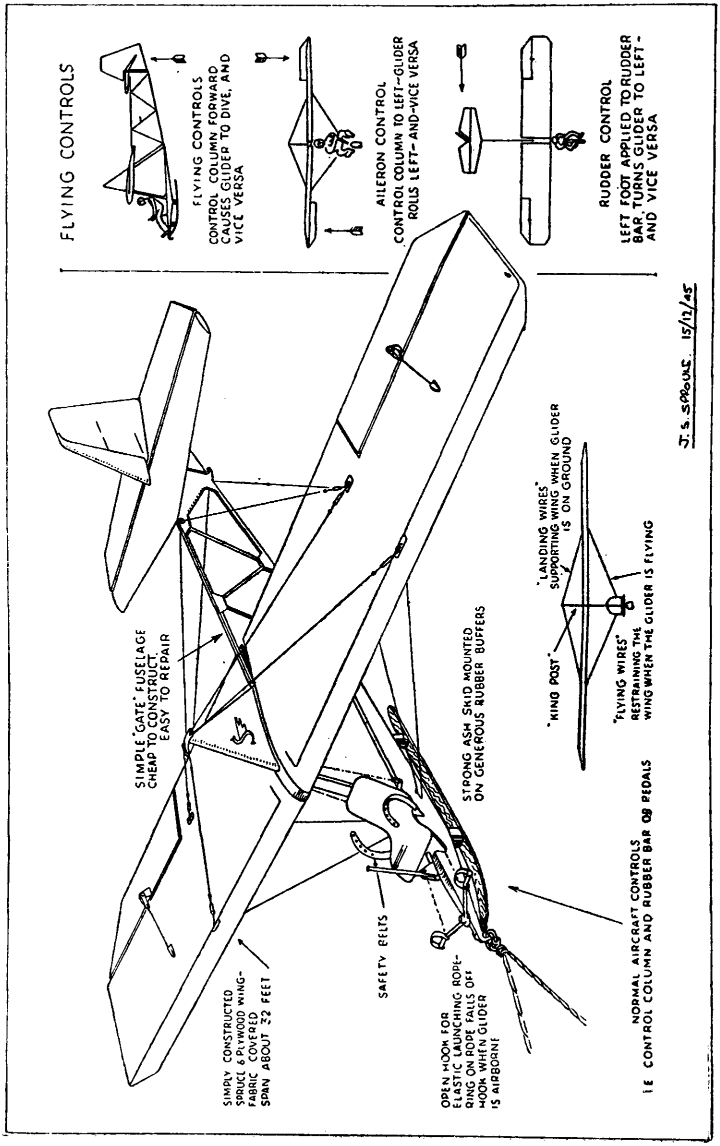


FIG. 20. Principal parts and flying controls of a primary training glider

you can help turning the wheel of a motor car which is running off the road."

As the glider approaches the winch, the driver stops his engine and everything comes to a standstill. Up there, a crew composed of a couple of pupils are waiting. They have driven over in one of the old motor cars, and in less than half a minute they have turned the aircraft round and are towing it back. The "pilot" is running alongside, holding up the wing tip. By the time he reaches us again he is puffing and blowing.

No time is wasted. Once more the aircraft is turned into wind and the wire cable—which was also brought back with the towing car—is hooked on. Again the procedure is repeated, and one by one the pupils get their first "slide." But although the training appears to be going forward at a breakneck speed, the instructor finds time to speak to each pupil about his faults. One was much too slow in making his corrections, another seemed to forget about the rudder, while a third moved the forbidden elevators through their whole distance of travel.

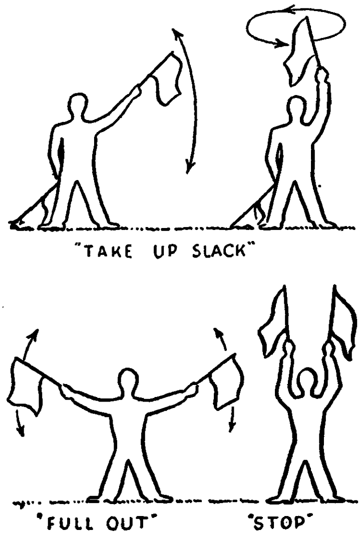


FIG. 21. The Club code of hand signals used in glider training. The signals in the upper picture are interchangeable

"I reckon," said the instructor to this pupil, "that you looped the aircraft five times in thirty seconds by pulling on the stick." But he says it with a smile, and the general feeling is that it was quite a fair joke.

Then at last it is our own turn. We are into the bucket-seat and strapped up in a few seconds. The feel of the controls is new and exciting. The control column moves easily in all directions. We can stir it round, as though we were mixing a suet pudding. We are actually trying this, when the quiet voice of the instructor breaks in on our ears. We didn't realise that he was standing over us.

"That's all right," he says, "try it out . . . try the rudder, too . . . see how easily it moves."

A gentle push with one foot against the bar on which it rests (this is illustrated in Fig. 22) makes it move through its whole distance. By twisting round our head, we see behind us how the rudder surface on the end of the tail boom has responded. We are thinking how simple it is when the instructor again speaks . . . "when you are actually flying, and even when you are being pulled across to the winch, you will find a firm resistance to any movement you make . . . it is caused by the force of the wind on the control surfaces. This will help you, rather than hinder, for both the stick and the rudder will be brought back by the airstream to their neutral positions if you take your hands and feet off."

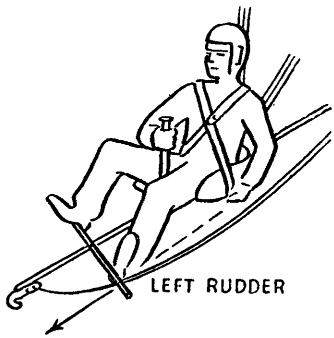


Fig. 22. Movement of controls for a gentle left turn. Control column a little to the left, a little left rudder.

"I was flying Spitfires once," he adds, "and the airstream is so powerful, when you are flying at top speed, that any movement of the control column needs considerable force, yet on the ground the Spit's controls are exactly like a training glider's."

It is not long before we have grasped the principles, and after a "rocking test," during which we practice making the corrections for gusts, the signal flags are brought out and the wire hooked up to the ring. This is our big moment of the day. We see the steel wire begin to tighten . . . it bends a sprig of heather and then snatches at our bows. We are jerked forward and are conscious of feet running at our wing tip. We are looking ahead, far ahead as we have been told, and as soon as the horizon tips, we move the stick in the opposite direction—knowing that the opposing wing has begun to drop. We are just beginning to think how very easy it is, when a really big gust lifts us clear off the ground, and for one terrific moment we are definitely flying. We don't know what to do . . . every scrap of book knowledge has gone right out of our head, and another second of this will paralyse us with panic. But far out across the heather, the winch-driver has seen what has happened. He slows down his engine, and the glider sinks gently back through a couple of feet of clear air, and the slide continues as though nothing unusual had happened. We haven't recovered from the sensation before the slide is over and we are at rest again.

"Not bad," says the instructor, "but you forgot to keep your stick forward."

That night we lie in our bunk under the old rafters of the farmhouse re-living the highlights of a memorable day. Around us are the shadowy forms of our fellow-members, blanket-wrapped, snug in the communal warmth of a dormitory. It is better to spend the night this way . . . to pay our half-crown for a bunk, so that we shall be ready again in the early morning, instead of making the long trek into the hills from our home . . . and it's cheap, too . . . perhaps ten shillings for the whole week-end. By Monday morning we shall practically be a qualified pilot . . . not quite perhaps. That last slide wasn't too good . . . kept on over-correcting, first one wing down, then the other . . . but we'll get it right tomorrow . . . gliding . . . the sound of it . . . the feel of it . . . with the whole sky for a playground to learn and explore . . . to learn and explore. It's a great sport.

CHAPTER FOUR

THE STORY OF THE WEATHER

The story of the sky—how the world's weather is made—air movements—the effect of the sun's heat, and of moisture in the air—cloud formation and thermals—the lapse rate—different kinds of clouds—how to recognise different weather effects.

WE saw in the last chapter what happened when we went for the first time as a new member to a gliding club. It won't always be like this . . . at all gliding clubs. There are many methods of primary training, and many different types of site on which it is given. Some clubs have no soaring ridges and rely for long flights on the lift of thermals. Some have ridges, but do their launching from the bottom of the hill instead of from the top (as at the London Club near Dunstable). Still others rely on a tow from an aeroplane for their launch, or on an elastic rope which catapults a glider over the edge of a cliff like a paper slug (see Plate 4.)

The wealthier clubs, and the A.T.C. organisations, have been able to dispense with old motor cars for retrieving and towing, and by a system of endless cables have speeded-up instruction on the calm days by pulling in both directions.

But whatever methods are used and whatever the types of aircraft, they all ultimately depend upon the same conditions for soaring flight—a vertical element in the wind. So the story of the sky, and the winds which blow in it, are common to any place at any time, and they must be learnt if the beginner is determined to make a good pilot. It is a great story, and it has a wide literature of its own. Much of it was theory before man learnt to fly and prove the truth of it, and much has been not only proved but discovered for the first time by sailplane pilots in search of greater heights. The forces within the thunder-clouds, the upward rush of the standing wave—by which men have climbed to over 20,000 feet in gliders—and the gentle turbulence of the summer thermals, are cases in point.

Perhaps the first and most important thing to establish in our minds is the minimum strength of upward current which can be used for soaring. However high the wind, it cannot keep a glider airborne unless it has a sufficiently powerful upward component in addition to any horizontal velocity. The solution to the problem is contained in the figure for the minimum rate of sink for any particular sailplane when it is flying at its best gliding angle.

Another glance at the drawings in Fig. 14 provides the answer. The high efficiency sailplane, to which pilots graduate after learning on the less-efficient, training models has a minimum sink of about two feet per second. It is clear, therefore, that if this aircraft flies through a body of air which is rising at four feet per second, the net gain in height is two feet per second, or 120 feet a minute.

If, on the other hand, the intermediate type of glider is used, which has a rate of sink of three feet per seond, the net gain is only one foot per second, or 60 feet a minute. Lastly, the primary type of aircraft, with its steep gliding angle and its sink of about seven feet per second, would not climb at all under these conditions. The speed of the rising air is insufficient and the aircraft would descend at a rate of three feet per second.

Hence, the currents in which the soaring pilot can afford to remain, depend upon the efficiency of his aircraft. But they must never be less than two feet per second, and if he is to climb, as opposed to remaining where he is, they must be more—even if he flies the most efficient glider obtainable. Let us see what the world's atmosphere can do in the way of providing such currents.

PLATE 8. It was in this Minimoa sailplane that Mr. P. A. Wills broke both the height and distance records. Today it is still one of the most efficient types in existence.

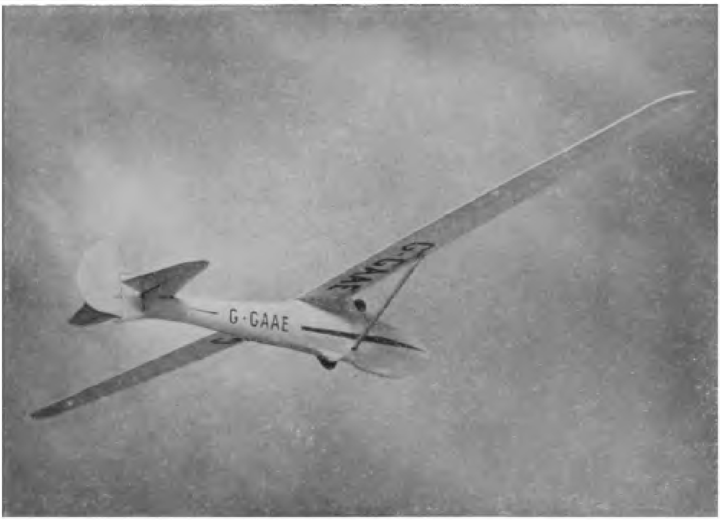


PLATE 9. The Kite II, Britain's first post-war high-efficiency sailplane. Gliding angle is 1 in 22. Rate of sink, 2.2 ft. per sec.

Plate 10. The Weihe, a German high-efficiency plane flown by the author. It is notable for its natural stability and great powers of penetration.

Plate 11. Instrument board of the Viking. An electric turn and bank indicator makes cloud flying a practical proposition.

One day I was flying a sailplane along the crest of a fine ridge, just managing to maintain a height of 500 feet. I kept in the updraught created by the wind striking the face of the cliffs below. After I had been cruising backwards and forwards for perhaps half an hour, a storm approached from across the plain—a great line of clouds with a swirling veil of rain hanging from their leading edge. They drove downwind at a tremendous speed, and in a few minutes had blotted out the sun. Simultaneously, a pair of arms seemed to hook themselves around my wings and lift me at great speed into the sky. The rate of ascent was actually 1,000 feet in 30 seconds, which was quick enough to outclimb any type of aircraft except a fighter.

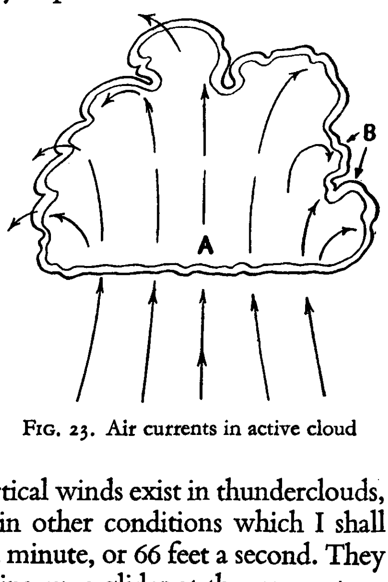


FIG. 23. Air currents in active cloud

When the British height record was broken at 14,170 feet in 1939, part of the ascent was made at an even greater speed. It has been proved that vertical winds exist in thunderclouds, and probably under certain other conditions which I shall describe, up to 4,000 feet a minute, or 66 feet a second. They would be capable of carrying up a glider at the same rate as the fastest interceptor fighter used during the 1939–1945 war.

Such currents bring with them their special dangers. As the air rushes upwards, other air from above descends to take its place. The two columns often lie next to each other, with no intervening gap of calm, resembling express trains passing on adjoining lines. As an aircraft passes from one to the other, it may have its wings torn off. The glider pilot is, therefore, careful before he exposes himself to such primitive forces, and he always wears a parachute. Fig. 23 shows the typical currents inside a thundercloud.

At the other end of the scale are the more gentle currents by which we seek our daily sport. It is the record breaker, or the pilot looking for new experiences, who deliberately penetrates the bastions of the thunder-heads where the currents are swiftest.

I give below a simple table which shows at a glance the speeds in which a pilot ordinarily expects to climb under the most common conditions.

CLASS OF CONDITIONS	SPEED OF RISING AIR IN FEET PER MINUTE
Inside thunder clouds (cumulonimbus) ..	2,500 to 4,000
In air ahead of a cold front (A hail storm for instance	2,000 to 2,500
Inside big cumulus clouds	2,000
Underneath big cumulus clouds	600 to 1,500
In a bubble of warm air which has broken away from the ground (a thermal) ..	
(*a*) When near the ground	250
(*b*) At 1,000 feet	600
In air rising over the crest of a hill (hill lift)	200 to 800

It will be seen that the speed of the rising air in each case is greater than the minimum required to suspend an intermediate, or secondary type of sailplane. This is the class of aircraft which is available to qualified pilots at every club.

But the bare statement of the conditions are insufficient to make a successful soaring pilot. The man who has flown heavy bombers, just as much as the newcomer to the sky, has to recognise them and to understand how they arise. I have myself flown towards a mighty cumulus (a photograph of such a cloud is given on plate 12) convinced that I would find a powerful up-current beneath its purple base, and then on exploring its shadows discovered only a smooth rush of a stable air around my wings. Greater experience would have told me that the cloud was decaying, that its toppling turrets were signs of collapse from which all activity had passed. Again, I remember a day on which I was swept into the grey sky by the powerful tow of the winch, to be left nearly a thousand up in the teeth of a half gale above a perfect soaring ridge. I sank slowly and inevitably to 50 feet above the crest, and failed to win another inch of height. In a wind only half as strong, I had soared over the same ridge on other occasions up to 1,500 feet. It is important to understand why such disappointments occur. To do so, we must unashamedly study the construction and behaviour of the atmosphere.

Air Movements

Soaring flight is possible because the air moves vertically as well as horizontally over the earth's surface, a statement made previously, but not so far explained. It has this property of vertical movement through the law which says that when a gas is heated, it expands, becomes lighter, and rises. This, combined with one other factor, is the key to every secret in the world's weather and, incidentally, to the success of the soaring pilot. The other factor—and let us remember this, for it is responsible for the nature of the weather—is the ability of the air to hold moisture. Were there no moisture in the air, there would be no clouds, no rain, no fogs, in fact, the world as we know it wouldn't exist, for there would be no life.

The depth of the air over the earth's surface is about 1,000 miles. At the top it is very thin and unable to sustain life, but lower down, the weight of the air above "thickens" it, so that at a distance of five miles above the ground a man can breathe and live.

This idea of the air having weight is at first difficult to understand. Yet it is a fact that one hundred thousand million tons of it (100,000,000,000 tons) have to be moved to one side before a depression can be formed, and such a depression is produced over the Atlantic on an average of once a week during the winter. We recognise it as typical windy and rainy weather.

Another way of appreciating the weight of the air is to remind ourselves that it will push a column of mercury up a glass tube to a height of 30 inches. In this case, the pressure of layer upon layer of the atmosphere, right up to the limit of its existence, will drive the equivalent column of mercury to this height. We use the fact to make barometers.

We should know these things, but because we are seeking to become glider pilots rather than meteorologists, we can ignore all but the first three miles above the surface. It is in this belt that the weather is made, and though air currents sometimes continue to rise as high as six miles, and even 16 miles over the equator, their manufacture takes place within three miles of the earth's surface.

The Effect of the Sun's Heat

If the air, with its moisture content, is the raw material of the weather, the sun is the furnace which heats it and keeps the brew in a continuously active state. Let us make a quick survey of the world's weather system, for if we understand it, the purely local air currents upon which the glider pilot relies become equally plain.

The heart of this system lies in the tropics. Here, the sun is almost directly overhead, the heat rays striking the ground vertically and creating air temperatures averaging nearly 100 degrees Fahrenheit. The result is that a vast blanket of very hot air gathers around the waist of the earth.

Now, we have already seen that hot air expands, grows lighter, and therefore rises. It is, consequently, easy to picture a continuously rising mass of heated air moving ever upwards into the great oceans of space 60,000 feet above the ground.

When this air rises, a fresh supply must move in from somewhere else to take its place. It is here that the ice caps over the North and South Poles play their part. In these ice-bound regions, the air is super-cooled—and cooling has the opposite effect to heating. In other words, the air contracts instead of expands, and becomes heavier instead of lighter. It may be mentioned, in passing, that this is the reason why the barometer (which is merely an instrument for measuring air pressure) is always higher at the Poles than it is at the Equator.

From the foregoing, it will be obvious that the heavy, cold air about the Poles will have a tendency to flow in towards the tropics, and take the place of the hot air which has risen into the upper strata of the atmosphere. The final result is a system in which cold air tends to flow towards the hot places of the earth, and hot air to move outwards. As the latter cools and sinks, it in turn will fill up the gap left by the cold air from the Poles, thus creating a continuous circulation, manufacturing not only world weather, but accounting directly for the great Trade Winds upon which mariners used to rely. Only one further comment is necessary. Because the world is revolving about its axis, the great air currents do not move in a straight line. They are given a curve by the movement of the revolving earth below them.

This, then, is the first principle of world weather. One other thing only needs to be added to it. It is simply that the sun does not heat up the surface of the land and sea equally. This is an important factor to glider pilots, for depending upon it is the creation of the local thermal currents upon which he so much relies. We shall study these later, and it is sufficient in the meantime to remember that the air over the great land masses rises to much higher temperatures than the air over the great sea masses. There is, therefore, a tremendous surge of rising air over the equatorial continents, reaching its peak at about midday when the sun is at its highest; and a much smaller effect of the same law over the equatorial seas. The flow of the currents is, therefore, far from smooth, or of equal volume in all places. It is for this reason that local storms, and even such widely-spread phenomena as the monsoons, exist.

The Effect of Moisture in the Air

Now the ability of the air to carry with it a large proportion of moisture has a profound effect on the climate, and it is at this point that the world weather system begins to impinge directly on the glider pilot's outlook. The reason is that the moisture is liable at any moment to form itself into clouds, and if these clouds become continuous, they will shut off the heat of the sun, and as soon as this happens, there will be no more hot ground to make hot air and, therefore, no thermals by which the glider pilot can rise to the clouds. When there are no thermals, there may be other forms of rising currents which may be used instead. But I shall show presently that they are not only much weaker, but generally outside the range of practical flying.

In the meantime, let us see exactly what happens during the formation of these all-important clouds. There are two main considerations which govern their manufacture:

1. The amount of water vapour present.
2. The temperature of the air.

To deal with the air temperature first, it is well known that air which is warm will suspend more water in an invisible form than air which is cold. This is most easily understood by drawing the parallel case of a glass of water to which salt is gradually added. There will come a moment when no more salt can be dissolved, so that any further addition will lie as a deposit on the bottom of the glass. However, if the water is now warmed, it will be discovered that an appreciable extra quantity can be put in. The hotter the water, the more salt it will absorb.

Now assuming that a glass of hot water is saturated with salt and then allowed to cool. The reverse action takes place, and salt which was previously held in invisible suspension will be "thrown out" and fall as salt crystals to the bottom. This is exactly what happens when moisture-laden air is cooled or warmed.

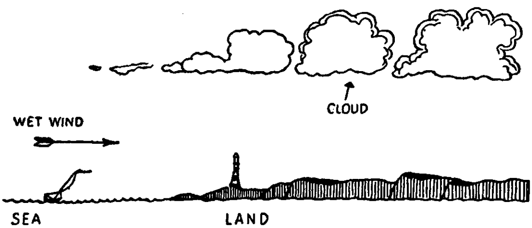


FIG. 24. Diagram showing how wet air from the sea forms clouds as it passes over *cold* land

The extent to which the air is saturated depends on where it has been. If it has made a long journey across the ocean—such as air carried to Great Britain across the Atlantic on a westerly wind—it will be very wet. If, on the other hand, it has blown across a great continent, it will almost certainly be very dry. In one case, cloud in some form is almost a certainty, while in the other the trend is towards clear skies.

One cannot, however, say that wet air will always produce clouds, or that dry air means an empty sky. This will be finally decided by the rise or fall of its temperature. For instance, the land to which it comes may be very warm, so that instead of new clouds forming, the old clouds which came with it from the sea will actually be dissolved and we shall enjoy clear skies. This corresponds to heating the salt-saturated glass of water. Suppose, however, that the land is very cold—such as during a frosty night—then the same air will be cooled as it crosses the coast, and the result is not merely cloud, but fog. This corresponds to the salt-saturated glass of hot water being left to cool in the larder.

Cloud Formation and Thermals

It will now be understood that when a body of air is cooled beyond a certain point (known as its dew point) that its water content will condense and a cloud will be formed. The condensed moisture is in the form of tiny droplets of water one thousandth of an inch in diameter. These may band together and form bigger droplets, and if they grow in diameter to more than one-hundredth of an inch, they will fall out of the cloud as rain.

These general principles may now be applied to the weather system as a whole, so that we can see at a glance the conditions which will give rise to the formation of cloud. As soon as we have done this, we can consider the conditions in direct relationship to gliding. There are only two important points—the formation of clouds by the movement of large masses of air, and their formation owing to local heating of the ground by the sun.

In the first case we are considering the great air currents generated at the equator. The warm air from these regions is flowing north (in the northern hemisphere), while simultaneously cold air from the Pole is flowing south to take its place. The meeting-place of the two currents will form what is known as a "front." One of the effects of the collision is to create a circulatory system of the cold and warm air. They flow round each other, keeping themselves to themselves, and finally creating a mighty revolving whirlpool in which the cold and warm streams retain their own sectors. These systems are known as depressions.

This in itself is easy to understand, until we remember that the air currents which are playing this game of "chase me Charlie" are capable of moving up and down as well as sideways. The warm air stream, for instance, will be either climbing over the back of the cold stream—because it is lighter—or being undercut by the cold air and forced upwards. Thus the game is played in three dimensions, and we get what is known as "cold fronts" and "warm fronts." The former can best be described as a line on the ground where a wedge of fast-moving cold air overtakes warm air ahead and pushes it upwards, while the latter is another line on the ground where the positions are reversed, and it is the warm air which catches up the cold, and climbs over the top of it.

In both cases, great masses of cloud may be formed. Whether the "front" is warm or cold, it is the warm air which has to get out of the way by rising, and as it rises it cools and expands. We have already seen what happens in such a case: its moisture is condensed in the form of clouds as soon as its temperature falls beyond the critical point called the dew point. These are clouds formed by the movement of large masses of air.

The other important clouds owe their origin to more humble parents. They are local in their conception and exist only because the sun heats the ground unevenly. I have already described two occasions where the sailplane in which we were flying struck a thermal. In each instance—and in every similar instance—the sun has heated a particular patch of ground faster than the ground round it, and this in turn has built up a bubble of warm air which has finally broken away.

A field of corn, for instance, will absorb the sun's heat faster than a field of grass. The roofs of a village, or an expanse of concrete, such as is found at aerodromes or big

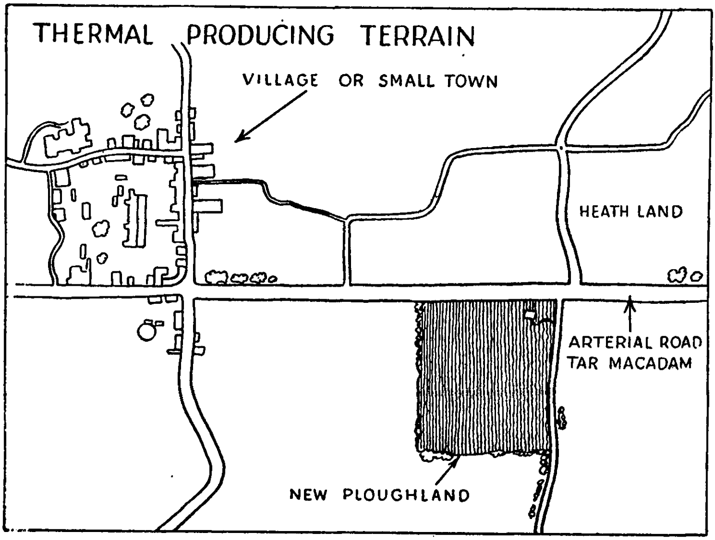


FIG. 25. Examples of thermal-producing terrain

road junctions, will similarly warm up quickly, and even ploughed fields, rocky hillsides, or patches of chalk in the land will enjoy the same advantage (Fig. 25). In each case, the air immediately above the warmer ground will heat up, and there will come a moment when it will break away and rise into the sky. It has been estimated the temperature rise over the surrounding air need only be two degrees Fahr. for the bubble to "unstick" (see Fig. 26).

We therefore get a situation in which a small mass of air, a few score of yards across and perhaps two or three degrees warmer than the air around it, starts a journey to the sky. At first it will move slowly, but as it gains height, it will enter layers of cooler air, to which, by comparison, it will be warmer still. This accelerates it, so that an initial speed of two feet per second may have increased to 10 or even 20 feet per second at 3,000 feet. The bubble will continue to rise so long as it remains warmer than the air around it.

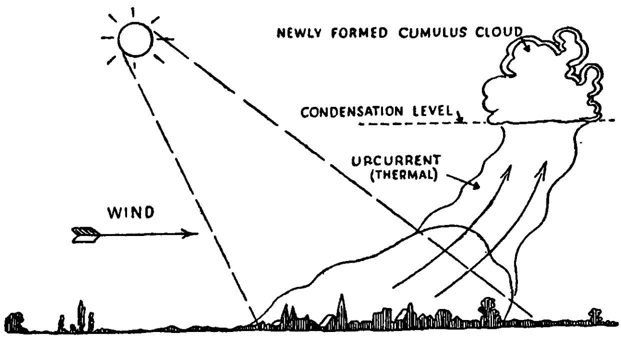


FIG. 26. The formation of cumulus clouds. The village is absorbing heat of sun more readily than surrounding terrain and creating a stream of rising air

There will come a time, of course, when the temperature inside and outside the bubble will be equalised, for the higher it goes, the colder are the strata through which it floats, and the more rapid will be its own cooling. When a balance is struck, the bubble will rise no higher. Normally, this state is reached at some height below 7,000 feet.

Now, so far we have explained the birth of a thermal without mentioning the birth of its cloud. The latter is due to the gradual cooling of the bubble, and consequently its inability to suspend its original amount of moisture. The cooling process usually reaches its critical phase before the thermal has reached its ceiling. It usually begins to condense into a new cotton-wool cloud (cumulus) at between 2,000 and 4,000 feet. On a sunny day at about 11 o'clock—as soon as the earth has begun to warm up—we have evidence of this process all round us. In a patch of blue sky there suddenly appears the white wisp of new cloud, and even as we watch, it grows and solidifies, so that at the tender age of five minutes it may have become quite substantial. It is only when the air in the bubble is very dry that no cloud forms. When the air is wet and the sun very hot, the thermals will be correspondingly numerous and powerful. Great masses of cloud will form all over the sky, and because of a wonderful process known as the "latent heat of condensation," the clouds may thrust their turrets upwards for thousands of feet, finally building into thunder-heads, which will give birth to a great storm. This "latent heat of condensation" is a somewhat frightening term. But it only means that the process of condensation releases a fresh supply of heat, which in turn will tend to keep the thermal rising, building up the cloud as it goes. The more moisture there is in the air, the greater the heat produced as it condenses, and the greater the urge to keep on going up. The process only reaches its logical conclusion when such a mass of cloud is formed that the earth below is cut off from the sun, and the "conflagration" is doused at its source.

Now let us translate what we have learnt to the soaring ridge. We left it at the moment we were about to fall asleep in the bunk-house, worrying over our mistakes, single-minded in our enthusiasm, and determined to make a good pilot. The ensuing days and weeks, or perhaps just week-ends, will demonstrate most of the phenomena described in the previous pages. The commonest source of rising air is generated by the wind striking the face of our ridge, and it is this class of current which we shall see used most often. The only condition necessary to its existence is that the wind should be from the right direction, and as it blows from the west nearly three hundred days in a year over the British Isles, the ridge is chosen facing that way. So our chances of seeing others soar, and of soaring ourselves as soon as we are qualified are good. It is only if we happen to join the club at about Easter time that the truth of this assertion may seem doubtful. For at this time of the year the wind has an established habit of blowing from the east.

The Lapse Rate

If we are observant, and, above all things, a glider pilot must be observant, we shall notice that the aircraft which beat up and down over the cliffs do not always cruise at the same height. On the dull days with overcast skies, the greatest height obtainable will appear to be a bare two or three hundred feet, while on the bright days anything up to 1,500 feet is the rule. Hidden in this phenomenon is the last fundamental secret which the glider pilot must know. Although I have left its mention until last, it is a vital link in the long chain of events which leads to successful soaring.

The meteorologists will tell you that the height obtainable over the soaring ridge with any given strength of wind depends on the "lapse rate." This is the drop in temperature of the air for every thousand feet of height. On the good days—with the sun shining and cumulus clouds building up in a blue sky—the drop is often about 5½ degrees (F.). On the dull, overcast days, it may be as low as 2 degrees (F.), or it may even be warmer at 1,000 feet than it is at ground level. In the last case there exists what is known as an "inversion."

Let us see how this temperature gradient affects the rising currents. Imagine a wind which strikes the face of the soaring ridge. From the foot of the hill it is forced upwards, and as a result the airstream will pass into a colder stratum, depending on the height of the ridge. If the ridge is 500 feet, and the lapse rate five degrees, then the crest will be 2½ degrees colder than the foot, and air entering this region will be "boosted." On the other hand, if the temperature is the same at the top as at the bottom—which happens when the lapse rate is zero—then there is no tendency for the air to rise higher. It will, instead, turn to follow the contours of the ground and continue its way horizontally across country.

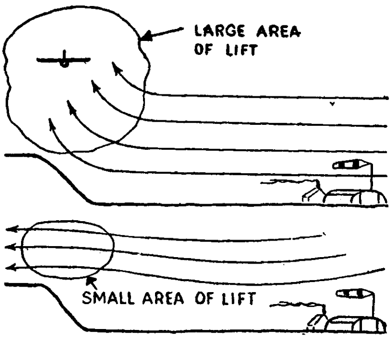


FIG. 27. The effect of high and low lapse rates on hill lift

The resulting areas of lift are illustrated in Fig. 27, and it will be noted that with a high lapse rate, the height attainable by a glider is about 2½ times the height of the hill.

Experienced pilots can generally estimate the lapse rate by looking at the sky. Cumulus clouds with big vertical development are the surest signs that it is high. An overcast sky with low clouds and drizzle are a certain sign that it is low. But the weather report, even as it is given over the wireless, is often a good guide. When the announcer uses such a phrase as a "cold front is approaching," or even "the weather will be colder," it is a strong indication of a high lapse rate and unstable air conditions. Many gliding clubs make special arrangements with their nearest airport, where the meteorological officer, who is in direct contact with Air Ministry, is able to give the official readings. These are taken several times daily, either by aircraft which are sent up to take the temperature at different heights, or by balloons which transmit the information automatically by small wireless sets.

With this knowledge at their disposal, the club members can estimate whether it will be a good or a bad day for soaring before ever they leave their homes. All that need be remembered is that the higher the lapse rate, the greater will be the boost imparted to rising currents and, therefore, the better the conditions for flying.

The View from the Ridge

If you are one of those who form the habit of walking across the moor to the crest of the soaring ridge immediately after breakfast, ostensibly with the idea of giving a learned opinion on the flying possibilities for the day, you will learn more rapidly to read the signs of the sky than you would by staying behind, or merely reading this book. You will see clouds of many different kinds, and by experience you will interpret them.

Come with me to the top of the Hartside ridge in Westmorland, and we'll try to estimate between us the value of the clouds. This ridge is a steep face marking the western boundary of the Northumberland moors. It falls 1,500 feet into the green pastures of the Eden valley, and beyond it in the distance the blue-grey line of the Lake District heights cuts the skyline into jagged edges. There are puffy white cumulus clouds over these distant peaks today, but the sky in between is the palest unruffled blue. The only other cloud in the sky is immediately above the moors behind us. Let us see what is happening.

The wind is our first concern. It is blowing in our faces from the west, and over the tops of those distant peaks at the other side of the valley. Beyond the peaks is the sea, so the probability is that the wind is a wet wind. On this evidence, it is a certainty that the airstream has struck the far side of the hills, to be forced upwards into colder strata where it has reached its dew point and formed the line of clouds. After it has crossed the high ground, it has resumed its horizontal passage below the level of its dew point, so that no further clouds are formed until it has reached our own ridge. Here, it has obviously struck the 1,500 foot face and again been deflected upwards. Its impetus has carried it once again to its dew point and produced the clouds over our heads.

This is a simple case, and we write down our findings as "orographic cumulus." (See Fig. 28). We can further deduce that the ridge soaring will be quite good, but that the empty sky over the valley denotes stable air, so that soaring beyond the immediate hill lift will be impossible.

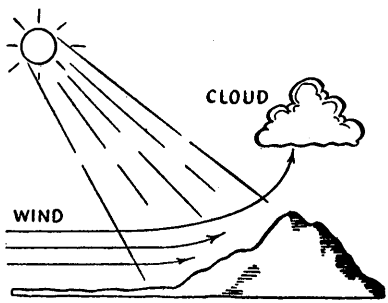


FIG. 28. Formation of "orographic cumulus" by hill up-current

Later in the day we notice that the clouds over the distant mountains have grown taller, and that here and there over the intervening valley, small fresh clouds are forming, growing as they drift towards us. It is obvious that the day is improving. The sun has been at work, warming up the floor of the valley unevenly, generating thermals which are reaching their dew point at about 3,000 feet where they are forming the new clouds. We can say now that it will be worth a pilot's while to explore the air over the valley on the chance of picking up one of the rising bubbles. If his search is successful, we can predict with certainty that he can reach 3,000 feet.

At lunch time, however, conditions don't look so good. Since noon, there has been some high, flaky white cirrus at about 20,000 feet on the horizon, and this now covers the sky with a thin veil through which the sun shines as though through frosted glass. The cumulus clouds at 3,000 feet still continue to form, but their vertical development is less. In another hour, the whole of the upper sky turns to a more uniform grey, and where there was high cirrus, there is now a level blanket of dull-looking stratus. It is, furthermore, lowering gradually, so that the upper layer is now only about 10,000 feet from the ground. Underneath the stratus, the cumulus still exists. But it is more broken, and has no healthy-looking turrets.

We prophesy with confidence the arrival of a warm front, probably rain before nightfall, and mist around the ridge-top where we are standing. The immediate conditions veto the possibility of anything but ridge soaring, for the sun has already been cut off from the valley by the stratus overhead, and we doubt very much whether even the ridge-lift will be good for much longer. These warm fronts have the habit of destroying the lapse rate. When this happens, the wind will come pouring over the ridge with no inducement to carry on any higher.

Our forecast of rain is the natural one, associated with a warm front. As we saw earlier in this chapter, the phenomenon is one in which a body of warm air has overtaken a body of cold air, and has commenced to climb over the top of it. The cirrus cloud at 20,000 feet was the first sign of the approach of the front. This was the moisture which had condensed out of the warm stream as it had risen to great heights over the back of the cold air. In Fig. 29 there is a diagram of the conditions existing when we first saw the cirrus clouds. About five hours later the system, which is moving at 40 m.p.h., will have brought the front itself from the Atlantic to our doorstep, and here—at the point of contact between the warm and the cold air—we may expect rain and low cloud.

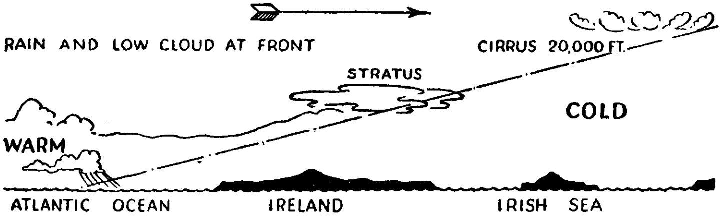


FIG. 29. Diagram showing the effect of a warm front advancing at 40 m.p.h. in the direction of the arrow

By repeating our visit to the hill top on other days, we shall see evidence of different conditions. Sooner or later, the ridge will be approached by a black line of clouds such as has been described earlier in this book. By their length—stretching from horizon to horizon—and by their great vertical development, we recognise them as harbingers of a cold front. In this instance it is the cold air which is overtaking warm, undercutting it by the thrust of its own weight. The warm air is being pushed violently upwards, and the clouds we see are the result of its condensing moisture. If the launch of a sailplane can be timed to coincide with the arrival of the front, we can predict for it an exciting climb to great heights, and if the pilot remains on the edge of the clouds, he will be carried downwind with the storm until it blows itself out. In this connection, we must remember that weather is never static, and that whatever we are describing—warm fronts, cold fronts, or thermals—the conditions are ever changing. The front may be developing or decaying, the clouds growing or dissolving, and when we make our forecast, we must estimate their state.

On another morning the conditions will be different again. The air is still and hot, and the blue sky quickly fills with cumulus clouds which build up to increasing heights. Eventually a great range is formed, towering even higher into the sky, its flanks tinged with yellow and its crests a snowy-white 20,000 feet overhead. Here is the practical manifestation of what we have already discussed—the creation of a potential thunderstorm. The whole massif is being fed by rising thermals, whose moisture content is adding fuel to the bonfire as it condenses and generates more heat. These are the clouds for the record-breaker, for the pilot with courage, determination, and a serviceable parachute.

How different these conditions are from the early morning in whose stillness a human voice can be heard a mile away. Up on the ridge top, the sun is shining in a cloudless sky, but down below in the valley is a sea of fog. The cold, heavy night air has trickled down the slope at our feet, covering the low ground, which during the hours of darkness has radiated its heat into the starlit sky. The air, cooling still further, has formed the fog, but we can predict that as the day advances, the sun will warm the ground again, which in turn will warm the air, so that its moisture will be reabsorbed. By midday, perhaps, the ground may even be hot enough to start generating thermals, so that in spite of the windless conditions, a pilot launched from the ridge crest would probably find a rising current sufficiently strong in which to circle and climb.

On yet another day there is a strong wind from the east. It pours over the ridge and rolls down the slope into the valley where, on most normal days, it would continue its course until it struck the lake district mountains in the west. Today, however, something strange has happened, for there are three unaccountable, sausage-shaped clouds lying parallel to one another in an otherwise clear sky. The first is almost immediately over the crest of the ridge, and the others lie some five miles apart over the valley (see Fig. 30).

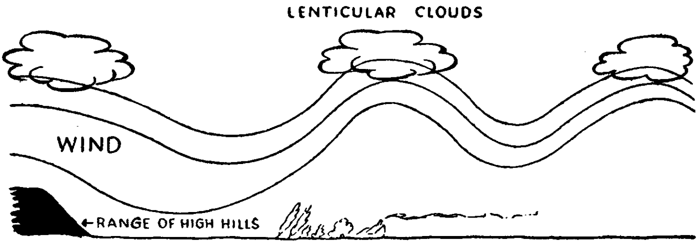


FIG. 30. The production of a "standing wave"

We have good reason for making our prediction today, for it was beneath one of these unmistakable clouds that a pilot started a flight in 1939 which ended more than 10,000 feet up. The airstream had risen at the foot of the hill into the shape of a great wave, forming this strange cloud (which is known as a lenticular) at its crest. A second and third wave had formed downwind, just as a submerged rock in a stream of water may form waves on its downstream side.

We are lucky to see this phenomenon, for the conditions of wind, lapse rate, and humidity are critical as to its formation, and may only be present on half a dozen occasions in a year. It is described commonly as a "standing wave," and it is safe to say that any pilot who succeeds in contacting its upward portion will rise faster than in any other kind of current. We can also say that if he is unlucky and flies into the downward portion of the wave, that his rate of descent will break another sort of record, and possibly his glider as well.

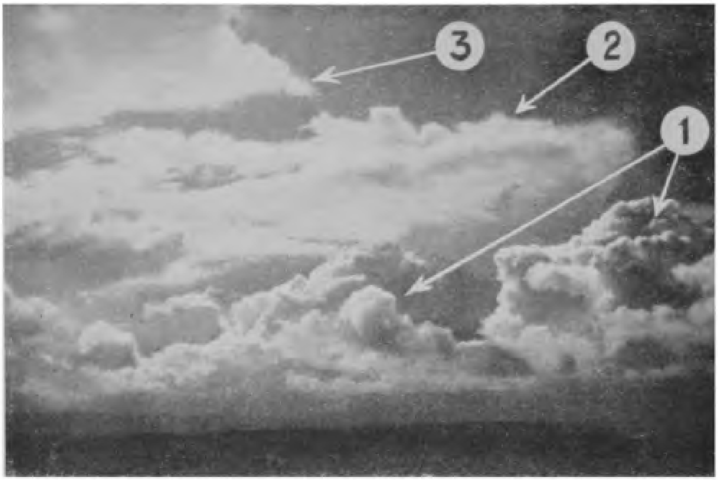


PLATE 12. Cloud formations: 1, Fully developed cumulus heads in which extreme turbulence might be expected ; 2 and 3, Anvils formed over cumulus (ice crystals)

PLATE 13. A lenticular cloud which has formed at the crest of a standing wave which has formed into the side of the Grampians. Photograph taken by the author at 12,000 feet.

PLATE 14. This picture shows damage done on the ground 12,000 ft. below the lenticular cloud shown in Plate 13. The wind has cut a channel through the wood. 1,000 trees came down.

CHAPTER FIVE

SECOND LESSONS IN FLYING

Second lessons in gliding—the pupil progresses from his 'A' to his 'B' certificate, and finally makes a soaring flight of five minutes to earn his 'C' certificate. Requirements for the Silver "C" and the Golden "C"—advanced gliders and their instruments—blind flying instruments—construction of a high efficiency glider.

EACH night under the rafters of the warmly-lit clubhouse there are gathered round the fire the members of the club in every stage of their flying education. The pilot, who has already accomplished half a dozen cross-country flights, shares his knowledge with newcomers to the soaring ridge. The holder of the Silver "C," who reached 8,000 feet during the afternoon in a cumulo-nimbus cloud, discusses blind flying with the ex-bomber pilot whom we met on the day we joined. The latter has much knowledge to bring the club, but equally he himself has almost everything to learn. His recognition of cloud-types, and of the weather which brings the great air currents is yet to be attained. We ourselves are keeping pace with him in this department, for we are studying the science of the sky, and keep our eyes and ears open for practical examples of its manifestations.

On the flying side—where we are still beginners—the first goal is an "A" certificate—awarded for a flight of 30 seconds in a straight line. How long it will take to obtain depends upon when the instructor considers it is safe to send us up to 600 feet. Such a height will be necessary before the glide of a primary trainer can be stretched to the necessary half minute. The goal seems a long way off, but as we listen and learn, we begin to put our flying training into its true perspective, and as this understanding comes, we feel that we are finally a real member of the gliding brotherhood.

The "A" Certificate

A pilot progresses more quickly if he can take instruction on consecutive days—and proof of this is given at the summer camps organised for the benefit of those who want to learn in a short time. Yet an apt pupil, who can only attend at the week-ends, may leave the ground after half a dozen slides, a point which stresses how quickly the feel of the air comes to young hands. As each slide is from 400 to 1,000 yards, and takes up to a maximum of 120 seconds, it will be seen that it is possible to reach the stage of being airborne after only 12 minutes ground experience. The high-road to gliding can be claimed to be much shorter than the road to the first solo flight in a power craft—usually eight hours. The truth of the matter is that it is easy to fly, and that difficulties are only experienced in the higher art of advanced soaring.

As soon as the instructor is convinced that his pupil has mastered the trick of keeping his wings level, he will give the driver of the winch orders to increase his speed. The aircraft will now leave the ground if the elevators are not kept depressed by holding the stick forward. It is a big moment for the pupil, for he is about to fly solo for the first time in his life. His instructions will be clear and to the point.

"Hold the stick in the neutral position, and ease it gently back when you think you have attained flying speed. The aircraft will leave the ground, and if you now ease the stick forward again, it should continue to fly parallel to the earth about three feet up."

The pupil is warned of two things at this stage. The first is to remember that he still has to keep his wings level, and the second is to put the nose down by pushing on the stick should he be in the slightest doubt about his altitude. I once knew an instructor who regarded the latter order as so important that he threatened his pupils with physical violence if they didn't obey him. It is certainly true that over-confidence will sometimes tempt a pupil to keep on climbing so that he finds himself twenty or thirty feet up. I have seen a pupil panic after this has happened. In a powered aircraft, the sequel would probably be a dive into the ground. In a glider, the winch driver can come to the rescue. By slowing down his engine, he can lower the aircraft back to earth, even though its nose is still pointing upwards and its wings are stalled.

The more usual sequence of events is for the first flight to be a procession of hops (see Fig. 31), in which the skid comes

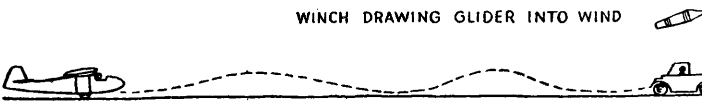


FIG. 31. Training hops—"ground sliding"

into more or less violent contact with the ground every twenty or thirty yards. This does no one any harm, and is merely a sign that the pupil is over-correcting on the elevators—just as in the earlier stage he was over-correcting on his ailerons.

The pulls across will be continued at a low level—a maximum of ten feet—until the pupil can maintain a more or less constant height during the flight. I use the words "more or less" intentionally, for absolute accuracy is impossible owing to the surge of the towing cable. During this stage, the interworking of the elevators and the ailerons will become automatic. That is to say, the pupil will unhesitatingly pick up a wing which begins to drop, just as he will pull the aircraft out of a dive, or take both actions together should the necessity arise. He will also learn to check the yaw of the aircraft with the rudder, a matter which I have already said is so instinctive that it is difficult to avoid doing correctly.

Stage three is the "high hop." This time the pupil will be told to continue the climb to about thirty feet before levelling out to make his flight across the level field. But now he will have to undertake the landing entirely unaided, for as he approaches the winch, the driver will stop his engine and the ring at the end of the towing cable will drop off the nose of the glider (see Fig. 32). For the first time, he will find himself

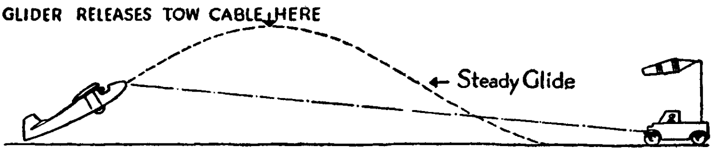


FIG. 32. The "high hop"

in free flight, and he will at once find it more pleasant and, by first impressions, easier to fly accurately. There will be no uneven surge from the cable which has made it so difficult to keep a constant height and course. But the danger in this new sense of security is that he should overlook the loss of the power which has kept him airborne. Whereas previously he could keep on flying so long as the pull was provided by the winch, he must now rely on gravity—and to bring this into play he must point the nose towards the ground. If he fails to take action, the aircraft will gradually lose flying speed, stall, and descend in a manner which will spoil the glider, if not the pilot.

Hence, the instructor's order on this occasion is most emphatic. It is to lower the nose by pushing the stick forward immediately the pilot ceases to feel the pull of the cable. There is no doubt when this moment arrives, for the winch-driver shuts off his power suddenly.

It will only take about five seconds to reach the ground from 30 feet, yet much can be learnt during this short period. The first piece of knowledge is the correct gliding angle, and this is something which is arrived at by a combination of the sound of the aircraft as it travels through the air, and a visible estimation of the glide path. The danger is not to dive into the ground by pointing the nose down at too steep an angle, for the pilot has not yet been born who is so devoid of natural instinct that he will not pull back on the stick to level out before he touches. The risk, small though it is, is that he will ignore the instructor's advice and try to prolong the glide by flying too slowly. If he does this, the usual result is a stall followed by a rapid loss of height on an even keel, which leaves the pilot with a sore behind through violent contact with the earth, and probably some broken flying wires. The height is generally insufficient for the full effects of a stall to develop.

There is, however, no reason why the flight should ever end in any but the orthodox manner. We are taking our flying seriously—which means that we intend to obey the instructor to the best of our ability, and not to show how clever we are by remaining airborne for as long as might be possible were the aircraft in the hands of an expert. The policy of the beginner is, therefore, to fly the aircraft rather faster than he knows to be strictly necessary—and his invaluable guide to this end will be his ears. I have already described the song of the wind which is a part of all gliding flight. This is the stage when it is used practically. The ears take the place of the air-speed indicator, which is only fitted to the more advanced machines—and if this seems strange, let me say that at the low speeds used in gliding I would back my ears for accuracy against the finest instrument ever made.

More difficulty is likely to be found in a smooth touch-down than in any doubts about the correct glide path. There is a pronounced tendency for all pupils to think that the ground is much nearer than it actually is, so that they commence the first part of the landing by levelling out too early. This has the effect of making a good landing six feet from the ground—the intervening distance being covered suddenly as the aircraft stalls. The fault, however, is so common and the results so mild (provided it is not carried to excess) that the pupil need not worry about it, except for a determination to do better next time. I think that the best

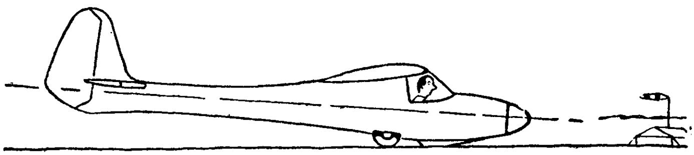


FIG. 33. The correct attitude for a touch down in a glider

advice which an instructor can give a pupil at this stage is to fly fast, and try to fly through the top of the waving grass—or the heather—which will be heard rustling on the skid. As the ground is approached, the first vital action is taken about 10 feet up, and consists of easing back the stick. This check brings the aircraft into flight almost parallel with the ground. As surplus flying speed is lost, the glider sinks until it is about to make contact with the earth at a slight angle. But just before this occurs, the pilot will ease the stick back a little further and so hold off. At this stage, he will hear the top of the grass brushing the skid, and he need take no further action. From this point the aircraft will land itself (Fig. 33). In a power aircraft, the hold off is prolonged by continuing the backward movement of the stick until the aircraft stalls and drops the last few inches in what is called a "three pointer." This technique is neither necessary nor desirable in a glider, and to this extent a glider is easier to land.

Three or four high hops will be sufficient for most pupils. The attempt on the "A" certificate may now be permitted without further instruction. As this is no more than an extension of the previous exercise, it is taken in the pilot's stride. I admit that the first time I found myself 600 feet above the earth in an open primary, looking at the ground between my legs, I had momentary qualms. The excitement was so great that I forgot about flying, and was only reminded that there was work to do by the sudden silence as I lost flying speed and nearly stalled. The subsequent glide, timed by an official observer with a stop-watch, took 34 seconds, and thereafter it was only necessary to fill up a form and send it with five shillings to the Royal Aero Club to be entered as a qualified pilot.

The "B" Certificate

The "A" test is taken over the club's landing field, and not over the soaring ridge. The air is, therefore, without the restless eddies which require continual correction for steady flight. Now, however, the pupil may possibly be allowed to experience the magic of the slope wind. It will depend upon whether the landing ground is large enough to provide the launch which will, in turn, provide the height to make a glide of 60 seconds possible. This is the longest of the three special flights which are required for a "B."

In any case, the pupil will graduate from an open primary (see Plate 2) to a more advanced aircraft with a fuselage. It may be a nacelled *Dagling* (see Plate 3) or a secondary type of trainer, such as is illustrated on Plate 5. The change from one aircraft to the other will not interrupt the pupil's progress, for he will find that the response to the controls of the more efficient machine is quicker and better; in fact, that it is easier to fly. Should it be necessary for him to fly out across the ridge, so as to obtain the lift for the longer flight, he will find the experience within his powers.

First, however, let us see exactly what is required. The "B" test demands two glides of forty-five seconds each, in each of which the pupil makes a broad S-turn, followed finally by the sixty seconds' flight to which I have referred. The turn is the new evolution which is important.

This development is approached by the instructor and his pupil in a commonsense and simple manner. The instructor will say, "to make a turn, it is necessary to put on a little bank and a little rudder . . . the turn to left being made by left stick and left rudder, and that to the right by opposite movement of the controls."

It sounds simple, and indeed it is simple. The pupil will undoubtedly be able to go into the air and turn his aircraft in any direction he desires in the not unreasonable belief that he can already fly. But let me warn him of a probable fault. The amount of rudder which is applied to match the degree of bank is critical. The two controls—the rudder and the ailerons—require to be balanced exactly. If too little bank is applied, the aircraft will skid outwards. If too much, it will slip inwards. In either case it will be an inaccurate turn. Happily, the pupil has a very excellent sense which will tell him what he is doing without reference to an instrument. If the turn is perfect, he will feel the wind blowing directly in his face. If he is skidding outwards, he will feel the wind on that side of his face away from the turn, or finally, if he is slipping in, he will feel it on the cheek which is to the inner side of the turn.

The correction for the skid is either more bank or less rudder, while that for the slip more rudder or less bank. Preferably, the pupil will be advised to apply less, rather than more of the required control, for in this way the turn will become more gentle. I have said that gentle S-turns only are required for the "B" certificate, and it may be added now that anything more than these are positively undesirable. While it is easy enough to make vertical turns, this is not the stage of the pilot's career to practise them.

This last sentence introduces a characteristic of all aircraft which becomes more and more pronounced as level flight is left behind. An aircraft on its side apparently no longer answers to the controls in the same way as it does when in a normal attitude. I say "apparently" because, in relation to its own flight path, the controls will always have the same effect. The change is in the relationship of the flight path to the ground.

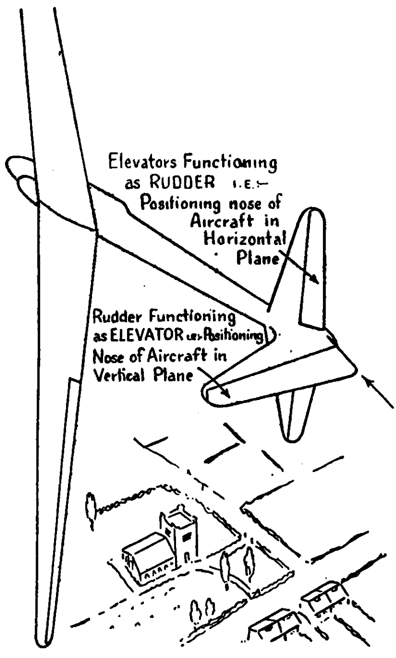


FIG. 34. Rudder—elevator changeover in a vertically banked turn

Let us delve into this more deeply, for while the gentle turns required for our certificate will hardly involve this characteristic, they will approach it sufficiently closely for us to require knowledge of it. If, for instance, we inadvertently make our turn too steep, we shall commence to dive as well as circle, and if we then pull back on the stick, which is the normal method of correcting a dive, we shall merely tighten the turn without raising the nose in relation to the horizon.

A little thought will show why this should be so. When an aircraft is on its side—which we call a 90-degree bank—(see Fig. 34) the rudder is moving through the same plane as that normally occupied by the elevator. The rudder therefore acts as the elevator so long as the aircraft remains in this attitude. Similarly, the elevator, which was previously parallel with the ground, is now vertical to it, and in the position normally occupied by the rudder. The elevator therefore acts as the rudder. In brief, the function of the two controls has been reversed.

I shall have more to say about this effect when I come to describe simple aerobatics. In the meantime, it is perhaps sufficient to suggest that a tight turn, say to the left, is obtained by movement of the stick to the left (which puts on the bank), plus a backward movement of the stick (which puts on the "rudder"), plus pressure of the right foot on the rudder bar (which puts on "elevator" and holds up the nose). It sounds complicated, but if you visualise an aircraft flying on its side, you will see that this combination is obvious and inevitable.

Let us, however, go back to the all-important business of winning our "B" certificate. When I took this test myself, I had only the vaguest theory of the points set out in the preceding paragraph, and felt at no disadvantage for the lack of it.

The two forty-five-second flights can be accomplished in the more efficient machine from 400 feet. The turns which are to be made should be completed with at least forty feet of height still remaining, and each turn should be entered at a slightly faster speed than that used during a straight glide. The reason for this is that an aircraft stalls at a higher speed in a turn, due to the effect of centrifugal force putting up the wing loading, and demanding, accordingly, a higher air speed over the wing to support the increased weight. In practice, a glider which stalls at 28 m.p.h. in level flight, will stall at 30 m.p.h. while making a turn with 20 degrees of bank, or at 36 m.p.h. with a 45-degree bank. In a power aircraft the effect is more pronounced, and I have stalled a fighter at over 200 m.p.h. in a tight turn—as compared with this particular aircraft's normal stalling speed of 75 m.p.h.

A safe flying speed for entering the turn in our secondary type of glider would be 35 m.p.h. with a limit of 20 degrees of bank. The margin of safety is therefore 5 m.p.h., which is adequate. Most training types stall at between 20 m.p.h. and 28 m.p.h., and, as a general rule, an extra 5 m.p.h. flying speed is a necessary safety precaution.

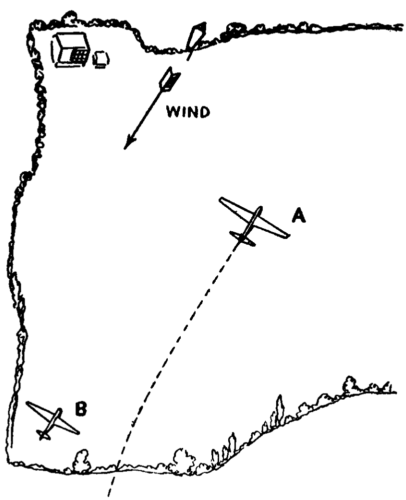


FIG. 35. Right and wrong touch down position in a landing field—"A" not "B"

The turns may leave us slightly out of wind, and it is now that serious notice must be taken of this new factor. The instructor will make himself plain enough on the point. "Your landings," he will say, "must be made directly into wind . . . and the final turn should be judged accordingly."

At the end of a cross-country journey this may be difficult to estimate. The smoke from a chimney, the washing on a clothes line, the way the grass is leaning over, or the direction in which cattle are grazing, are all indications. But on the training field, you will remember the direction in which you were launched, and should know without further reference the direction in which you should land.

The effect of a cross wind can be disastrous. In an extreme case, an aircraft landing at right angles to a wind blowing at 30 m.p.h. will itself be moving sideways at 30 m.p.h. Fuselage, wings and pilot are likely to part company. Even in a light wind, an aircraft with more than 5 m.p.h. drift is likely to damage its skid. Such a drift might be expected in a 20 m.p.h. wind when the aircraft is as little as 15 degrees out of true.

The final flight of 60 seconds will probably consist of a complete circuit of the training field. This may, as I have indicated, take in a brief section of the soaring ridge. It will be an exciting moment for the new pilot. As the circuit brings him over the ridge, he will fly from smooth air into rough. Immediate and constant corrections to the gentle buffeting of the unstable air will be required. But by now the pilot will make these automatically, and will be more conscious that he is climbing in the up-current. The additional height so gained will make sure that the flight exceeds the minimum of 60 seconds.

Another application to the Royal Aero Club, countersigned by the official observer, will produce the much-desired endorsement.

The "C" Certificate

The first two tests are preliminaries to the third and last, which is the real diploma of the qualified pilot. While there are two other certificates awarded for specific performances in sailplanes, the "C" is the licence which will make available to its holder the freedom of the ridge, and most of the club's aircraft. It is given for an observed flight of five minutes above the point of launch. As the requirement implies, it involves two or three beats along the face of the ridge in a soaring wind.

As a rule, the step between the "B" and "C" certificates is a short one. If the pilot is showing promise, half a dozen circuits followed by normal landings will persuade the instructor that he is finally fit for the ridge. A good soaring day will be chosen, a day when the lift extends several hundred feet above the crest. Under such conditions, there will be no question of the pilot failing to maintain height, and no temptation for him to fly too slowly.

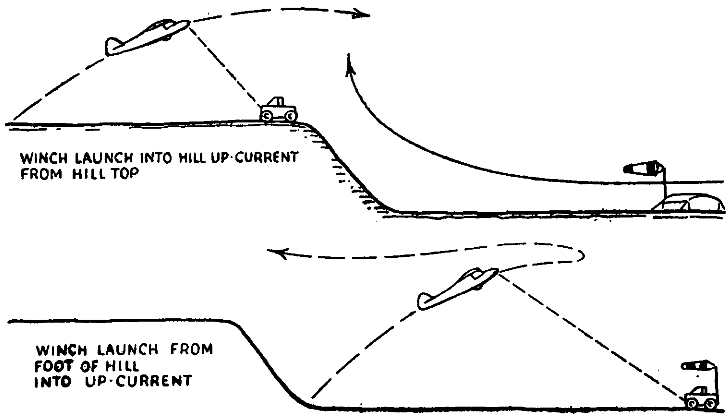


FIG. 36. A full winch launch into the area of lift, made from either the top or bottom of the hill

The launch on this occasion will, at most clubs, leave the pupil at about 700 feet over the ridge (Fig. 36). After dropping the cable, he will fly straight on until he enters the area of lift, when he will turn to right or left, depending upon the direction in which he will fly furthest without being compelled to make a turn and retrace his steps. The turn, when the time comes, will be made *outwards* from the ridge. The moment will be judged visibly—at the point where the cliff face ends, or alternatively, according to the orders of the instructor (see Fig. 37).

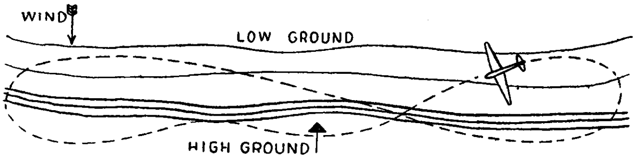


FIG. 37. Slope soaring—the pilot makes his turns at each end of his "beat" —into the wind

After five minutes or longer, the pilot will turn in, circle the landing field, and aim to make his touch-down at least one-third of the way across it. It may look well to put down the aircraft just inside the field, but it is undignified and expensive to fly into the wall or the hedge which guards it.

THE SILVER "C"

Continuous flights over the soaring ridge, followed by flights across the low ground ahead of it in search of thermals, will give the new pilot fresh ambitions. As soon as he learns the trick of "thermalling," he will itch to make a cross-country flight. If he is wise, he will resist it until he has at least thirty hours' soaring experience. By this time, he will have experienced several examples of the type of weather which favours long distances.

The Silver "C" is divided into three parts and requires a distance flight of 50 kilometres (approximately 31 miles), a height of 1,000 metres (3,281 feet), and a duration flight of five hours (which is a matter of physical endurance over the home ridge on a good soaring day). For each of these tests a sealed barograph is carried. This is an instrument which automatically records time and height.

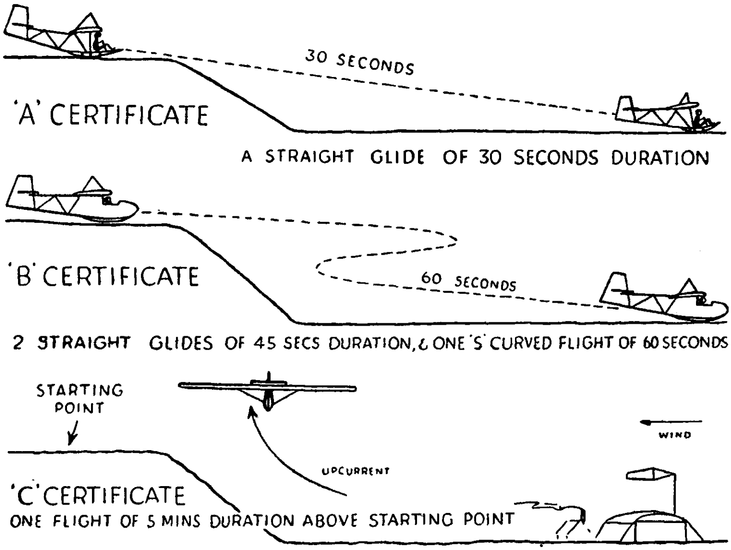


FIG. 38. The performance necessary for the three chief gliding proficiency certificates, shown diagrammatically. The conditions of issue for these certificates are laid down by the Federation Aeronautique International, but the issue is administered in Britain by the British Gliding Association.

THE GOLDEN "C"

In 1945 there was one British pilot holding a Golden "C." It is my opinion that there will be at least a dozen by 1955, and probably many more. It is an award with two conditions: the achievement of 3,000 metres in height (9,843 feet) and a distance of 300 kilometres (approximately 186 miles). The present British distance record of 209 miles was made between Heston, near London, and St. Austell in Cornwall. The next record may well start from the other end of the country—at Hartside in Westmorland, which I have already described. A flight from here in a north-west wind might embrace the whole length of the Pennine Chain and finish on the south coast, easily embracing the distance requirement for the Golden "C." The height of 10,000 feet, which for so many years eluded British pilots, may be achieved easily from the same site in its "standing wave," of which mention has already been made. Alternatively, any of the summer thunder clouds will provide the lift for the pilot who has the courage to face its tempestuous airs. Many pilots new to gliding are ex-service pilots who once made the night flight to Europe in heavy bombers. Their skill in flying on instruments, and their past experience of such phenomena as electrical storms and icing, will enable them to face the dark interiors of the thunder heads with more equanimity than the rest of us.

Advanced Gliders and Their Instruments

The successive stages of the pupil's progress, culminating in his "C" flight of five minutes, will have introduced him to more advanced types of aircraft. At the same time, he will have discovered with each advance new instruments in his cockpit.

The first of these is, of course, an air speed indicator—known as an A.S.I. for short. The next, and by far the most important in soaring flight, is a very sensitive rate-of-climb indicator, called a variometer. This is installed with an altimeter for showing the height, because the two are used in close conjunction.

Until a variometer was fitted to a British sailplane for the first time in 1933, no cross-country journey of note had ever been made. As soon as it was introduced, gliding took a tremendous forward step. It would be true to say that without the variometer—even with the experience which we now have behind us—all soaring except ridge soaring, would come to an end. Yet this instrument can be made for a few shillings and is among the simplest of all aids to flight.

Readers of the earlier chapters will have already understood that it is a device for showing the pilot whether he is climbing or descending. While the altimeter does the same thing, it only provides the information in stages of about 50 feet, as compared with stages of six inches on the part of a good variometer. The way in which a variometer works is shown diagramatically in Fig. 39.

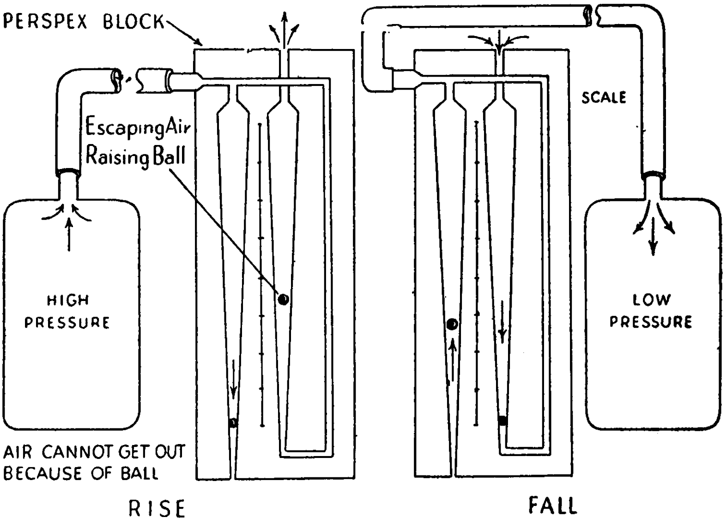


FIG. 39. Diagram showing the operation of the Slater Cobb variometer

The principle is based upon the well-known fact that a rise in height is accompanied by a drop in air pressure, and *vice-versa*. The sailplane which enters a thermal and rises one foot will immediately be flying through a stratum of air at a lower pressure. The variometer records the difference.

An air vessel, such as a vacuum flask, is used, and this is connected by rubber pipes through two tapered glass tubes whose opposite ends are open to the air. One tube is used for recording ascent, and the other descent. When the glider rises and the air pressure drops, a minute volume of air will flow out of the flask as long as the pressure inside is greater than that outside. This flow will pass through the first tube in whose base is a featherweight coloured ball. The ball will be lifted off its seat by the airflow and will be held up by it as the air leaks past. The tube is calibrated in inches and feet, and by the height of the ball the pilot will know the speed at which he is climbing.

In the case of a descent, the outside pressure will be increased, and air will accordingly flow *into* the flask. To do this it will have to pass through the second tube, as the first tube is now sealed by its ball (see diagram) and a new ball will be lifted off its seat by the flow. The readings, however, on this scale represent a loss of height. The great advantage of the instrument is that there is no appreciable time-lag between the change in air pressure and the record of it showing on the instrument. When a thermal is a bare 100 yards in diameter, which represents about five

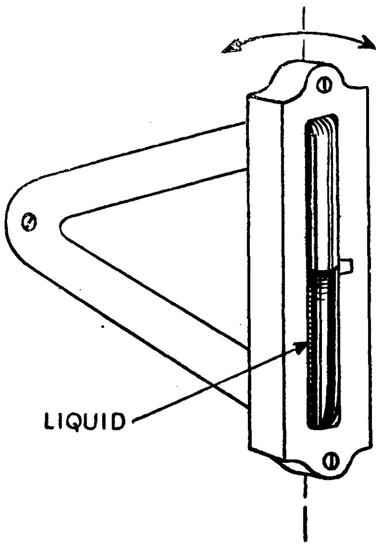


Fig. 40. Fore and aft level—or pitch indicator

seconds flying time, the importance of the pilot commencing to circle immediately is obvious. Only the variometer is quick enough to give him his cue.

BLIND FLYING INSTRUMENTS

The A.S.I., altimeter, and variometer are all the instruments which any glider pilot who does not intend to enter clouds requires. We have seen, however, that great heights are usually only reached by cloud flying—and this means blind flying. Hence, the most advanced sailplanes carry at least the minimum of additional instruments which will enable their pilots to maintain controlled flight after they can no longer see. Compared with the blind flying panel of a bomber—which may cost £300—the sailplane pilot manages with very little.

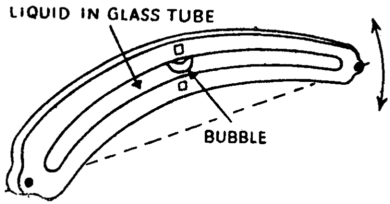


FIG. 41. Cross level, or inclinometer

The essentials are two glass tubes filled with a coloured liquid, one of which is mounted in the fore and aft plane, and the other in the lateral plane. The two instruments, which are of different shape, are illustrated in Figs. 40 and 41. They reveal to the pilot two vital conditions of flight. The U-shaped tube in Fig. 40, mounted fore and aft, will denote whether the aircraft is climbing or diving, while the second instrument, which is similar to a carpenter's spirit level, will denote whether it is skidding or slipping. This information is important when the pilot is making blind turns, such as are required when climbing up through cloud.

A more satisfactory instrument is a turn-and-bank indicator, for this will give the additional information of the

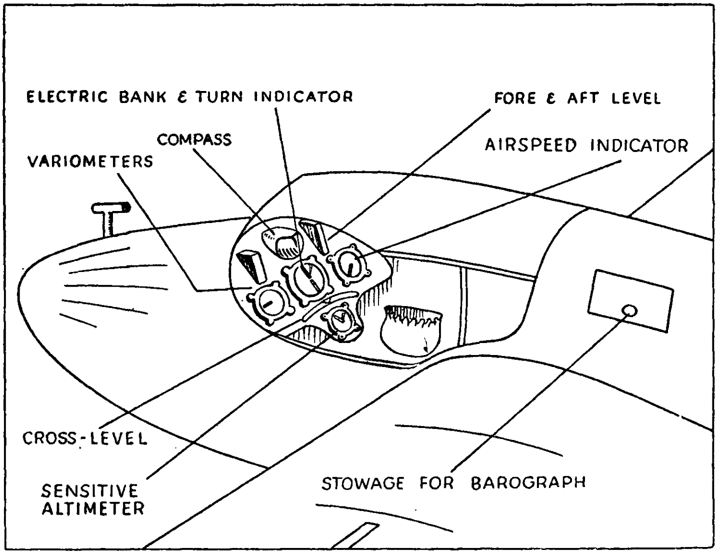


FIG. 42. The instrument panel of a typical high-performance sail-plane

amount of bank which the pilot has applied and the speed of his turn. This instrument is operated by an electrically-driven gyroscope and is comparatively expensive. The layout of the cockpit in Fig. 42 shows this instrument.

CONSTRUCTION OF HIGH EFFICIENCY GLIDERS

Every club possesses two or three sailplanes of high efficiency for the use of its more-experienced members. Curiously enough, these aircraft are much easier to fly than the less-efficient types, and the only reason for reserving them for the senior pilots is because, in the event of breakage, repairs are more costly. A photograph of one of the best high-efficiency sailplanes ever designed is reproduced on Plate 8. This is a Minimoa, of German design, and in 1945

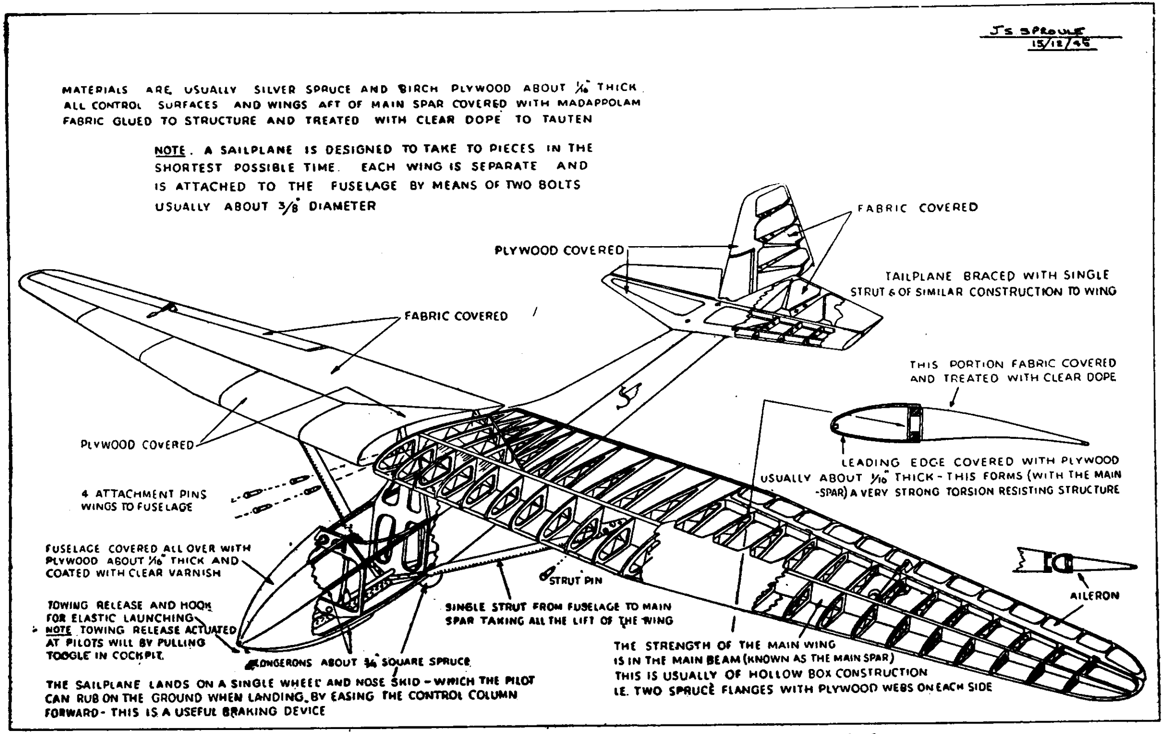


FIG. 43. Construction and principal parts of a typical sail-plane

it held both the British height and long-distance records. The following are its principal details:

Span	55 feet 9 inches
Wing Area	205 square feet
Wing Loading ...	3.24 lbs.
Weight	441 lbs.
Gliding Angle	1 in 26
Sink at 40 *m.p.h.* ...	2 feet per second

The materials which go into the construction of a sailplane such as this are the same as for the less-efficient types. Silver spruce and birch plywood of the highest grade are the principal raw materials. The spruce is used in all those parts subjected to high strain, such as the spars, struts, ribs and longerons. The plywood forms the stressed skin and is polished piano-bright so as to lessen friction with the air. The only important departure in woods is that used for the skid, which is of the toughest ash, steamed into shape, and shod with a mild steel sole.

The metal fittings are either drop-forgings or made of fabricated steel. Their positions are clearly indicated in Fig. 43. Control wires are supplied by specialist manufacturers. They are stranded steel cables with a breaking strain of at least 500 lbs. All wing-coverings behind the boxed-in leading edge are doped and varnished fabric, the surface forming a streamlined and slippery skin presenting the least possible friction.

Yet the difference between this type of aircraft and that in which our first lessons were taken is not so much in workmanship or material as in design. It is the shape of the fuselage, the manner in which it blends into the cockpit cover, and the exquisite faring of the wings and tail unit which promote the efficiency. I have stressed how important it is to keep drag at a minimum. In aircraft of this class, elimination of drag is carried to a degree which represents the limit obtainable by modern craftsmanship.

FIG. 44. The internationally recognised gliding badges issued with the three proficiency certificates by the British Gliding Association

CHAPTER SIX

LEARNING TO FLY A POWERED CRAFT

The difference between a powered craft and a glider—flying instruments—starting drill—take-off—simple aerobatics—landing—side-slips—cross-wind landing—forced landings—figures of eight.

THE sun was streaming into the cockpit, and the air was still and warm. Eight inches from the top of my head, on the other side of the transparent roof, a gale was blowing at 250 m.p.h., while the temperature was below zero. As I was a couple of miles above the earth with nothing to do but to keep the compass needle in its pre-ordained position, I began to while away the time by counting the instruments and switches in the cockpit. There were sixty-seven of them. The total seemed so large that I counted them again and found that I had missed one out. Sixty-eight dials, switches and knobs, crowded into a space where there was not room to turn round, stand up, or even stretch. When I closed my eyes, I could reach out my hand and touch any one of them I desired, and I knew what they were for and when to use them.

This isolated little memory pulled out of its place in the years is a useful illustration of the difference between flying a modern aircraft with an engine and an equally modern sailplane without one. Yet it is not the number of the instruments to which I would draw attention, but to the suggestion which lies behind them. The flight of a powered aircraft is checked and counter-checked a score of times by mechanical means, while the flight of a glider is controlled and supervised almost entirely by the senses of its pilot. I could fly a glider without a single instrument in the cockpit. To say the

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As Geoffrey Cumberlege publishes outside the United States of America and Canada the books issued by the American University Presses of Columbia, Cornell, Harvard, Johns Hopkins, Michigan, Minnesota, New York, North Carolina, Pennsylvania, Princeton, Stanford, Toronto, Yale, and by the Commonwealth Fund, and outside Australia and New Zealand the books issued by the Melbourne University Press, IT IS PARTICULARLY REQUESTED THAT HIS NAME BE ADDED IN THE REFERENCE, TOGETHER WITH THE ENGLISH PRICE same thing of a powered aircraft would be stupid and dangerous. While sensitive hands and a well-developed air sense mean good pilotage in both cases, in an aeroplane it is attention to the instruments and their readings by which these qualities are attained. Powered flight is a mechanical affair, gliding is a thing of the spirit and the five senses.

Having said this, it will be as well to add that the type of training aircraft in which the pupil will learn to fly has nothing like sixty-eight dials or knobs in its cockpit. It will have at the most, half a dozen flying instruments and as many engine gauges. Nor will their acquaintance prove a strain on the memory. Instruments develop recognition features like human faces, and as we instantly differentiate between twenty or thirty friends crowded at a party into the same room, so we know the layout of our cockpit.

As we fly a powered craft for the first time, we shall take off because the engine revolution counter is reading a certain figure, and the air speed indicator another figure. We shall come in to land after paying homage to other dials. If we try to substitute our natural senses for the instruments, we shall find ourselves in trouble and our instructor in the back seat complaining of our inattention.

An aeroplane is a glider with an engine. It can do one more thing than a glider, and one thing only. It can climb without the assistance of an up-current. Its flying controls and the manner of using them are identical, and the feel of them in the hands of the pilot is the same. If you can fly a glider, you can very nearly fly an aeroplane. A score of practice landings should be enough to qualify the experienced glider pilot to go "solo."

The engine transmits its power through a propeller, which is neither more nor less than a moving wing. A cursory examination of a blade of any propeller will show the curved surface of an airfoil—the shape of a wing all over again. It may be longer in comparison with its width, but there is no mistaking the characteristics.

A little thought will reveal immediately how it works. Being an airfoil, we know that should a stream of air flow over it, it will exert lift. Because the engine is turning it, creating such an airstream, we deduce that lift is produced. But we call it "thrust," because its direction is horizontal instead of vertical. The greater the air speed over the blades, the greater the thrust, and the faster we fly.

It is customary to learn power flying on a light aeroplane —which may have either one or two wings, and an engine of about 100 h.p. But it is not necessary. I once taught the ground engineer of my squadron to fly in eight hours on a twin-engined aircraft which weighed ten times as much as the average light trainer. Another friend learnt to fly in a fighter as he sat on his father's knee. His father was a famous test pilot, and his son is now the same. It is no more difficult to fly a modern, high-speed service aircraft than it is a Tiger Moth or a Miles Magister. The most that one can say is that either of the latter are cheaper to run and cheaper to break.

These lightly-built and lightly-powered machines have a cruising speed which varies between 90 and 120 m.p.h., depending on whether they are biplanes or monoplanes. The monoplanes are, of course, the faster aircraft, because they have less "drag." Their top speeds are perhaps 15 m.p.h. faster, while their stalling speeds are in the neighbourhood of 50 m.p.h.

The cost of obtaining an "A" licence, which allows a pilot to fly anywhere at any time, just as a driving licence entitles a man to drive a car, is about £60. This is a substantial increase on the £30 which was the cost before the war. This money will be spread over about 14 hours dual instruction and six hours solo flying. A pupil of average ability should go solo for the first time after eight hours instruction. If he shows great aptitude, he may be allowed up alone after five hours, or if he is slow, after 12 hours. The "A" tests consist, in brief, of a demonstration by the pilot that he is able to make a normal take-off and landing, fly accurate figures of eight, and finally make a forced landing on the flying field after he has shut off his engine at a height of 2,000 feet. In addition, he must pass a simple oral examination on the rules of the air—just as the new driver of a motor car must show that he knows the rules of the road. The cost of the licence is five shillings.

Let us now pay a visit to the flying club which we have joined and take our first lesson—as we did when we joined the gliding club. Much of the instruction will be common, so where the sequence of events overlaps, I shall not describe it in the same detail. Our object is to appreciate where the two types of flying differ, and see where we must adapt ourselves accordingly.

The club we have joined is equipped with Tiger Moths—a type of aircraft on which tens of thousands of pilots have been trained. When we arrive, a dozen of them are ranged on the hangar apron, each "signed out" as serviceable by the engineers. (There is a picture of a Tiger Moth on Plate 16).

We book our lesson at the flying office, put on helmet and gloves, and accept an invitation to take the front seat of the aircraft at the end of the row. The instructor accompanies us, and runs over the cockpit. This is a ceremony which has great importance. I have known experienced pilots spend two hours looking over their cockpits before they flew a new type for the first time. Admittedly, these have been service types fitted with a great many instruments, but any length of time which enables a pilot to put his hand on any control blindfolded is time well spent. In an emergency, it is instantaneous reference to the right "knob" which saves an accident.

An illustration of a typical cockpit in a training aircraft is shown on Plate 15. The two groups of essential instruments may be listed as follows:

FLYING INSTRUMENTS	ENGINE INSTRUMENTS
Air speed indicator	Revolution counter
Turn-and-bank indicator	Oil pressure gauge
Compass	Petrol gauge

The turn-and-bank indicator is sometimes omitted even from this short list. On the other hand, for more advanced training such as instrument flying, we shall find a much more elaborate panel. For the moment, this need not concern us, for we are essentially interested in passing the "A" test.

In addition to the six instruments, the aircraft will have four other controls not found on gliders. One of these is a tail trimmer, by which the aircraft can be "balanced" in a fore and aft plane so that it may be flown "hands off." The reason for this is that the pull of the engine affects the trim. When the engine is shut off, the aircraft becomes nose heavy; with full power, it becomes tail heavy. Were it not for the trimmer, a continual pressure would have to be applied to the stick to keep the aircraft in the desired attitude. The trimmer is operated either through a spring which is attached to the control column, so as to apply the pressure which would otherwise have to be exercised by the pilot, or by wire cables leading to small auxiliary panels hinged to the elevators (see Fig. 45). The latter gives the tailplane the extra lift required to restore the fore and aft balance.

Next is the engine throttle, which is an obvious addition, and lastly the twin magnetos switches and the petrol cock.

As we sit in the cockpit, we shall find that the throttle lies conveniently to our left hand, and that below this is the lever

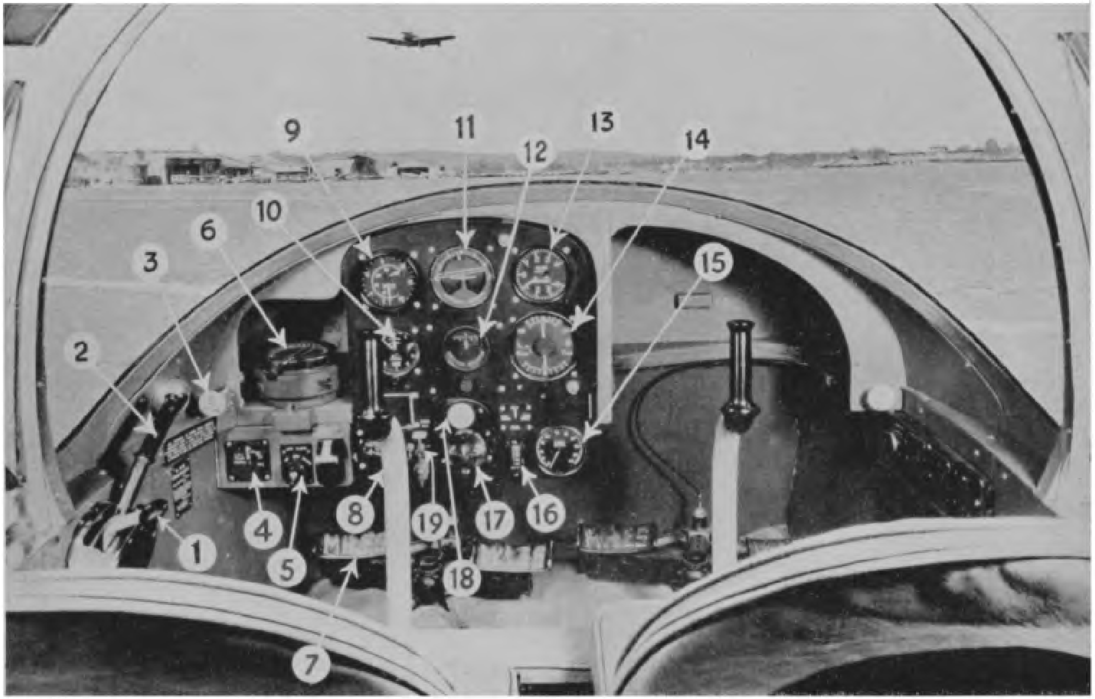

PLATE 15. Instrument panel of power plane : 1, Throttle ; 2, Parking brake ; 3, Mixture control ; 4, Flap indicator ; 5, Flap switch ; 6, Compass ; 7, Rudder pedals ; 8, Control column ; 9, Air speed indicator ; 10, Altimeter ; 11, Artificial horizon ; 12, Directional gyro-indicator ; 13, Rate of climb indicator ; 14, Turn and bank indicator ; 15, Revolution counter ; 16, Oil pressure gauge ; 17 and 18, Navigation lights ; 19, Magneto switches.

PLATE 16. A Tiger Moth, Britain's greatest trainer, commences a loop.

PLATE 17. Miles Messenger, a modern four-seater passenger aircraft suitable for training. When the author flew this aircraft, he reduced speed to 28 m.p.h. before she stalled.

operating the trimming device to restore "hands off" flight.

Looking round elsewhere, we shall find the petrol cock well forward on our left-hand side, the flying instruments

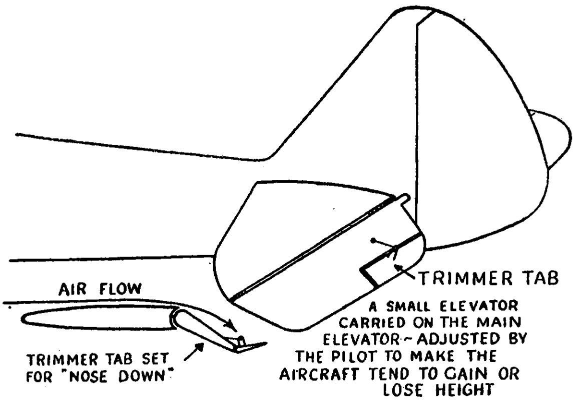

FIG. 45. The function and action of trimmer tabs

grouped neatly on the left of the instrument panel, and the engine instruments on the right of the panel. The stick and rudder bar will fall into position at our hands and feet just as they did on a glider.

This leaves the engine switches alone to be accounted for. They are fitted outside the cockpit on the left side of the fuselage, within reach of the pilot's left hand.

A duplicate set of all controls and instruments is fitted to the rear cockpit occupied by the instructor.

STARTING DRILL

The starting procedure is a rigid code designed for safety. Two people take part in it—the pilot and the member of the ground crew told off to stand by. First of all—after the position of the chocks under the wheels have been checked—

the ground crew sings out, "Petrol on," and the pilot repeats the words, at the same time putting the petrol cock in the appropriate position. Next, the ground crew calls, "Switches off," and it is the duty of the pilot to check that they are, in fact, "off," and then to repeat, "Switches off." This ensures that the engine will not kick while the ground crew carries out the vital duty of turning the engine over by pulling round the blades of the propeller. I have seen a man's arm taken off by a misunderstanding as to the position of the switches. The turning of the propeller sucks petrol into the engine and makes starting easier.

Immediately after this, the ground crew stands back and shouts, "Contact." The pilot flicks up the switches and repeats, "CONTACT." The propeller is then swung, and the engine should fire.

While the motor is warming up, which will take about five minutes on a cold day, the pilot will go through his cockpit drill. As the instructor is already in the back seat, this will be done under his supervision. This drill is again of vital importance. It will ensure that all those instruments already in operation are working correctly, that the petrol tank is full, that the safety straps are properly fastened and tight, that the "intercom." is "loud and clear," that all controls move freely, and, lastly, that the trimmer is forward (nose heavy) for take-off.

The next vital action is to run up the engine, and this is done by opening the throttle slowly to its full extent. Every aero-engine must attain on the ground a stated number of revolutions, and when each magneto is cut out alternately by depressing the relative switch, the drop in revolutions must not exceed another figure which is laid down. In this instance, we shall expect 2,200 revolutions, and a drop of not more than 50 revolutions on each magneto.

TAKE-OFF

The chocks are waved away by the instructor, the throttle is opened, and the aircraft moves away to the point of take-off. At this stage, we'll invite the instructor to take over while we listen to him on the intercom.

"You will notice," says his voice, "how the full movement of the rudder is required for manoeuvring on the ground . . . see how I keep using it . . . swinging the aircraft from side to side to make sure that the way is clear . . . this is necessary because we can see very little so long as the tail is on the ground."

The aircraft is now approaching the downwind end of the landing field. Before the instructor turns the aircraft into wind, he swings it for the last time so that he has a view of the sky across the boundary over which any other aircraft may be landing. Should the way not be clear, he will wait until the other aircraft has touched down and stopped. It has priority. The voice now comes again over the intercom. . . .

"Right . . . all clear . . . a last check round the cockpit . . . everything O.K. Open the throttle slowly to its full extent . . . stick forward to get the tail up . . . use the rudder to stop the swing . . . one eye on the air speed indicator . . . thirty-five miles an hour . . . forty . . . fifty . . . right, she's flown herself off the ground."

We are aware that this take-off is very different to that of a glider. The strong push on the stick against the slip stream of the propeller is new. The need to get the tail up quickly is new, although its need is obvious when we realise that this alone will get the aircraft into the flying position. A few moments of flight make other things immediately obvious. The noise of the engine, and the powerful rush of air around the windscreen in front of our face seem to act as a barrier between ourselves and the feeling of contact with the elements which we had in a glider.

Simple Aerobatics

At 1,000 feet the instructor allows us to take over the controls, with orders to fly straight and level. We find this very easy, in fact as easy as in our sailplane. On the other hand, we discover ourselves repeatedly checking the speed by the A.S.I. (air speed indicator), instead of trying to listen to the sound of the wind above the roar of the engine. When we try a turn, the aircraft responds perfectly to our touch, but here again it is to an instrument that we refer to check the accuracy of the turn rather than to our sense of equilibrium. The top needle of the turn-and-bank indicator, and not the feel of the wind on our face, tells us whether we are slipping or skidding (it should always be central). The truth that powered flight is a more mechanical affair than gliding is being borne in on us.

"We'll take her up another couple of thousand feet and try a spin," says the instructor.

This is something which is demonstrated early in the career of a power pilot. The manoeuvre is the inevitable result of a loss of flying speed and a stall, and is not merely dangerous, but fatal if we don't know how to correct it.

We open the throttle until it is nearly wide, and pulling up the nose until the speed sinks to 70 m.p.h., we gain the necessary height in a couple of minutes. We are now at 3,000 feet, at which spins or other forms of aerobatics can be practised safely. However inaccurately we handle the controls, there will now be plenty of height for recovery.

"We'll do this spin together," says the instructor and, as he speaks, the throttle is closed and the stick eased back to pull up the nose.

"Watch the air speed indicator . . . she'll stall at about 50 m.p.h."

The needle creeps back over its dial . . . seventy . . . sixty . . . fifty-five miles an hour. The aircraft is still under control, but everything is much quieter, with little engine noise and only a gentle sob of the wind, such as we knew in our sailplanes. But as the needle approaches 50 m.p.h. something happens . . . dramatically, suddenly, like a ladder being knocked from under our feet. The controls are instantly sloppy. The gentle pressure which we had been maintaining on the stick brings it back into our stomach. The nose, which was pointing at the sky, is now pointing at the ground. The left wing has dropped. There is a terrific sensation of falling . . . a feeling of impotence, which rapidly becomes one of exhilarating alarm as the earth seems to begin spinning beneath us. Through this confusion comes the calm voice of the instructor.

"We are spinning to the left . . . to correct this we check the turning motion by putting on full right rudder . . . at the same time the stick is moved forward so that we shall come out in a straight dive."

As he speaks, the controls move beneath our hands and feet, and almost instantly the spin ceases, though we are still diving at the earth. Now the air is shrieking once more about our ears, and it seems certain that we shall plunge into the ground. Then again comes the unruffled voice of the instructor.

"The spin has now been checked and we are in a simple dive. The air speed is 100 m.p.h., and we may therefore pull out and assume straight and level flight."

We feel the stick being eased gently back, and a heavy pressure on our seat as we come smoothly out of the dive.

"You will notice," says the instructor, "that we have lost a thousand feet."

As we are already qualified glider pilots, the instructor answers a request that he will now demonstrate a few simple aerobatics with acquiescence. Had we been pupils without previous experience, he would have probably considered that we were trying to run before we had learnt to walk.

"We'll start with a loop," he says, and suiting action to his words, the nose of the aircraft is put into a shallow dive. The speed rises from 90 m.p.h. to 130 m.p.h., when the stick moves gently back beneath our hands. Its total travel is no more than a couple of inches, but at this speed the effect of the elevator is powerful, and we come out of the dive in a smooth curve which presses us hard into the seat. The dive turns into a climb which grows steeper until the nose points vertically upwards. During this time the stick has been held back motionless. But now the instructor eases it still more towards him, and the aircraft comes over on to its back. Out of the corner of an eye we notice that the air speed has dropped to 70 m.p.h. Now the engine is throttled back, and the stick pulled still harder in towards the stomach. The nose comes round, and as the aircraft falls into a dive, the stick moves back towards the neutral position. In another moment the loop is completed. During the whole manoeuvre there has been no uncomfortable sensation. We could have done without the safety harness, for while we were upside down, centrifugal force kept us firmly pressed into the seat.

"Now for a roll off the top," says the instructor.

Again the nose of the aircraft goes down, and this time we complete the first half of a loop until we are upside down. At this point we see that the stick moves firmly to the left. A moment later, right rudder is applied. The aircraft, immediately answering the controls, turns smoothly over, the rudder holding the nose while the fuselage is on its side. As the aileron turn is completed the stick is brought back to the central position and the rudder straightened. We are again flying straight and level, although in the opposite direction.

Our instructor is beginning to enjoy himself, for he announces that the next on his programme is a slow roll.

"This is more difficult," he says, "but you'll get the idea if you follow the movements I make on the stick and rudder."

This time the throttle is opened to its full extent until we are flying at top speed. Then firmly and smoothly the stick again moves to the left. The aircraft responds by banking, until it is on its side. As the bank becomes vertical, right rudder is applied to hold up the nose. The turning movement is continued, and in another moment the aircraft is on its back. This time we hang in the straps as there is no centrifugal force to press us into the seat. The rudder has meanwhile moved back to central, and the stick—which is still over to the left of the cockpit—moved forward. Once again, the functions of the rudder and the elevator have been interchanged. (While we were on our side the rudder held up the nose. Now the elevator is doing the job again, but because the aircraft is on its back, the movement of the stick is forward instead of backward.)

The turn continues, and as we come out on to an even keel, the controls are smoothly restored to their neutral position.

"We'll do that again," says the instructor. This time, he points the nose of the aircraft at a little cottonwool cloud and tells us to keep our eyes on it. As the manoeuvre is executed, the cloud appears to revolve slowly about the boss of the propeller. We realise that we are being treated to a demonstration of accurate aerobatics by an artist, and we make another good resolution . . . we will try to make our own flying as polished.

Landing

"I don't think you'll have much difficulty in landing," comes the voice through the intercom., "but you must try to stall the aircraft on to the ground instead of flying it on, as you do in a glider."

We appreciate the meaning of this a few minutes later, for the instructor allows us to attempt the landing on our own. The result is a series of bounces across the field which are finally terminated by the instructor opening the throttle and "going round again."

"We'll try another one together," he says.

Once again the aircraft is climbed to a thousand feet and the field circled. The throttle is closed just before the final turn in, and the glide held steady at exactly 70 m.p.h. Over the intercom. comes the instructor's running commentary.

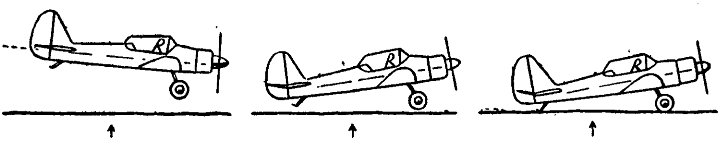

FIG. 46. Landing a power aircraft

"We are now approaching the boundary of the aerodrome, which we shall clear nicely . . . at a height of twenty feet we shall begin to level off . . . this is the first check . . . we're over the fence . . . a little left rudder to bring us directly into wind . . . that's better . . . now ease back the stick . . . fifteen feet up . . . ten feet . . . speed 60 m.p.h. . . . five feet . . . ease the stick back a little more . . . one foot . . . hold off . . . hold off . . . there she goes . . . bang the stick into your stomach."

The aircraft drops through the last six inches of space like a stone, contacting the ground simultaneously with both wheels and the tail skid . . . a perfect three pointer. A diagram of the aircraft's attitude is shown in Fig. 46.

The art of landing a powered aircraft is to stall it six inches above the ground. The fault of four pupils out of five is to stall it six feet up instead of six inches. The fifth pupil makes the less-dangerous fault of flying the aircraft into the ground, either bouncing, or making a "wheeler." It would probably be true to say that eight out of the ten first hours of instruction for an "*ab initio*" pupil are occupied in practice landings. At first, it appears extraordinarily difficult to judge the distance between the wheels and the ground. Then one day the pupil goes up and makes his first perfect three pointer. Suddenly it seems easy. He cannot understand why he could not do it before, and ever afterwards three pointers are the rule rather than exception.

I have said already that the glider pilot will probably make the less serious fault of flying the aircraft into the ground. Before I took up power flying, I had done some flying in gliders, and the attitude of my power instructor was interesting. "You are perfectly safe," he said, "but your landings look horrid." That was because I ran the wheels along the ground with the tail up and in the flying attitude, just as I had landed sailplanes. After two hours "dual," the instructor got out and said with a smile, "You can jolly well teach yourself to land . . . off you go."

It was a terrifying moment, but there was nothing for it but to go up and work out my own destiny. It took me a month to discover that silly little secret; then, like everyone else, I wondered why I had been so slow.

Side-Slips

In the course of instruction for our "A" licence, we shall be taught how to side-slip. This is a useful manoeuvre for losing excess height without gaining extra speed while coming in to land, and as it can be equally useful on sailplanes, we are keen to master it.

The time to use a side-slip is when we find ourselves at a hundred feet or more over the boundary of the field instead of the more usual twenty or thirty feet. The extra height is the result of a misjudged approach—although not so badly misjudged that it is necessary to go round again.

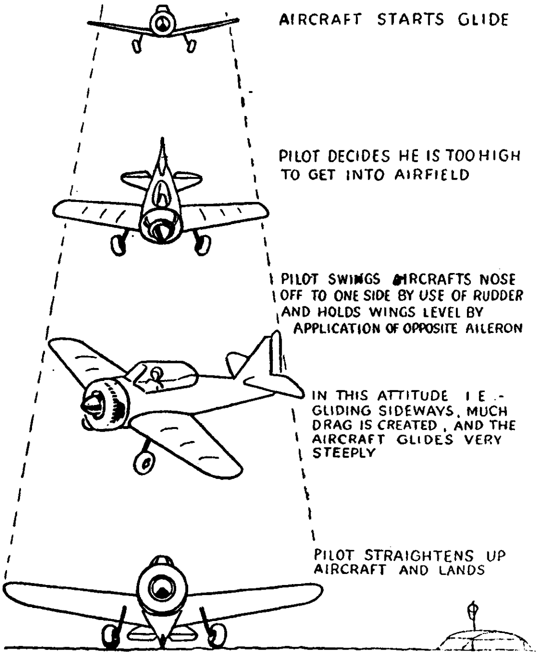

FIG. 47. The use of side slip in landing

It consists of yawing the aircraft to either right or left and applying opposite aileron. The path of the aircraft is changed from a straight glide to a crab-like progress in which one side of the fuselage is presented to the wind, while the inside wing is slightly lowered. In this attitude, the loss of height per second will be more than doubled, while the forward speed remains the same, and the machine is under full control. Fig. 47 shows the flight path and the attitude of the aircraft.

When the pilot has more experience, he will find that the slip can be made very steep and the loss of height extremely rapid. This does not mean that the nose of the machine is lowered, but rather that the amount of bank is greatly increased, which in turn demands a corresponding increase in the amount of top rudder to hold up the nose. In a steep slip to the left, the pilot will apply full right rudder and sufficient left aileron to put the left wing well down.

All training aircraft side-slip well. It is only in certain types of service aircraft and multi-engined machines that the manoeuvre is inadvisable. But the pupil must watch one point. The slip will have a tendency to put "drift" on the machine, and this must be allowed to subside before landing. The slip should therefore be concluded while the aircraft is still twenty or thirty feet above the ground.

Cross-wind Landings

While cross-wind landings are not required for an "A" licence, they may be mentioned here as they automatically follow on the procedure for a side-slip. I have just said that drift is a natural result of such a slip. If, therefore, a landing is to be made with the wind on our left, and we slip the aircraft to that side, straightening it out only just before the wheels touch, then we shall have sufficient drift to the left to counteract the effect of the wind in the opposite direction.

Forced Landings

Successful forced landings are the result of good judgment. They are fascinating to practise, and teach a pilot one of the first lessons of good airmanship—to watch the country over which he is flying and never to forget the direction of the wind.

One day, as we are flying straight and level with our instructor at perhaps a thousand feet, the throttle will suddenly be closed, and a voice will reach us over the intercom.

"The engine has failed . . . pick a good field and make a forced landing."

The first time it happens, we are likely to be in such a panic that we shall attempt to land downwind on the top of a wood or in a ploughed field.

The next time, we shall have our wits about us, and be able to select something which looks to be comparatively level grass, and without trees around it. As the approach is made, there will come a moment when the instructor will say, "that's enough . . ." and the throttle will be opened again without actually touching the ground. Gradually, we shall learn that the secret of such a landing is to keep an eye open for good landing fields at all times, and then when the emergency occurs, never to lose sight of it by turning our backs on it. Broad S turns, and perhaps a side-slip at the last moment, is the recipe.

Figures of Eight

The figure of eight, which forms a part of the "A" licence test, is required because it is the proof that the pilot has learnt to make turns accurately without losing or gaining height. The glider pilot will have no difficulty in achieving this, but others without previous flying experience will not find it so easy.

The procedure is for the pupil to select three points on the ground at equal distance from each other, and then to describe a figure eight, during which he passes over the centre mark and the two outside marks in a series of broad right and left-hand turns. The two outer marks will be sufficient if a convenient centre point cannot be found. Houses, ponds, and road junctions all make good marks. During the actual test for the licence a barograph will be carried, and this will record whether the pilot—who is now flying solo—loses or gains height during his turns.

CHAPTER SEVEN

AIRMANSHIP

The meaning of airmanship—its practical application on a cross-country flight. How to navigate—how to make allowances for the wind. Some rules of good airmanship.

I HAD an aeroplane in my squadron which a pilot belly-landed in a field after an engine failure. The repairs took some weeks, but in due course the engineers rang up to say that the aircraft was ready and would I arrange for a test flight. I decided to undertake this myself.

Now an aeroplane which has been damaged is given an exceptionally careful check before it passes out of the workshops. Knowing this, and in spite of it, I gave it another check of my own, beginning with the airframe, and ending with a run of both engines at full power. Everything seemed all right.

We taxied to the end of the duty runway, turned into wind, and received the green light for "go." I opened the throttles and should have been off the ground in a few hundred yards. Within measurable distance of the end of the runway, however, I was doing 90 m.p.h. with adequate engine revolutions, and was still on the ground. As there was not enough room to stop, I yanked the stick back and pulled her off. She flew normally, but was very nose heavy. At forty feet, I began to wind back the trimming wheel to restore the trim. The aeroplane immediately tried to dive into the ground. I stopped it by brute strength on the stick. So I wound the trimming wheel the opposite way and immediately the aircraft responded, until I was flying comfortably straight and level.

The control wires leading to the trimming tabs had been crossed. They had been inspected by at least three people, including myself, and had been passed as O.K. A normal result of the oversight would have been a funeral, followed by a court-martial.

Prior to this, I had always thought that my airmanship had been good. I had seen pilots break their noses on the gun sight through crash landing with a slack safety harness; I had seen them lose themselves in bad weather because they thought they knew the way and had left their maps behind. I had even seen them forget to lower their undercarriages before landing, and raise them before taking off. But not me . . . I was a good pilot, or thought I was.

Let there be no doubt about it—the quality of a pilot is measured by his airmanship. If the preceding paragraphs have not explained the meaning of this, pay a visit to the nearest airport and watch the drill of any of the commercial pilots before they take off.

But airmanship goes even deeper than attention to the specific details of this or that aeroplane. It is something which is in the bloodstream and works like an anti-toxin to the germs of a disease. If it is in your veins, you will never find yourself cutting a corner of the aerodrome, so that you can land ahead of another man, or low flying over your girl friend's house, or aero-bating a passenger without first having obtained his consent, or setting out on a cross-country flight without getting a weather report, or doing any of the thousand and one things which a good pilot might do, but never does.

Let us consider some of these things in detail. For the purpose of illustration we will suppose that a flight is intended from the London airport at Heath Row to Padstow in Cornwall. Many of the qualities of good airmanship are required on such a flight.

The first act of a good pilot is to obtain a weather report.

If it is unfavourable—that is to say if low clouds are reported over Salisbury Plain, or Exmoor, where the ground is high, or if the visibility is poor, he will then make his first decision. Should he take-off, or postpone the journey? The answer will show the first quality of airmanship—a knowledge of his skill, or lack of it. The man who has the makings of a first-class pilot is the man who knows his limitations. On the same day, at the same time, another pilot may set off on the same journey, and land safely at the other end. It will not alter the decision. What is safe for one man may be dangerous for another. Good airmanship means the ability to say "no" to yourself at the right moment.

Today the "met." man at the airport reports heavy industrial haze for the first fifty miles, gradually improving to the west, until from Exeter onwards, there will be bright sunshine and a clear sky. As we are fairly experienced fliers, we decide that we can deal with the haze, and we consequently go on to the next stage. What is the wind? The answer is 10 m.p.h. from 270 degrees (due west) at 1,500 feet.

So we leave the "met." office and go to make sure that our aircraft is ready. We don't accept the engineer's word for it. We scrutinise the daily inspection sheet for ourselves and see that every relevant column has the engineer's initials against it. Particular note is taken of the column which shows the state of the fuel tanks—petrol and oil.

Next we go to the flight office and plot a course on the maps. We have three of these, each to a scale of four miles to the inch. They are, of course, special aviation maps, which means that railways, lakes, woods, and hills are printed with particular clarity in bright colours. Our ordinary maps may show the roads in strong relief, but as roads are difficult to follow from the air, aviation pays little attention to them.

The first task is to draw a line in pencil from the London airport to Padstow in Cornwall, joining up at the boundary of each map. Measuring this, it is seen that the total distance is approximately 54 inches, which at four miles to the inch, is 216 miles. Now we take our protractor and read off the true course. This is 254 degrees. We now take our notebook and jot down the information so far received, and add to it the cruising speed of the aircraft at which we intend to fly. The list looks like this:

TOTAL DISTANCE ...	216 miles
WIND	10 m.p.h. from 270 degrees
COURSE	254 degrees
INDICATED CRUISING SPEED	130 m.p.h.

From this we must work out the course to steer by our compass, the speed over the ground and, finally, the time which the journey will take.

There are two things which will affect the course. In the first place, the needle of the compass will point to the magnetic north, and not to the true north on which our bearings were taken from the map. In the second place, the wind will tend to blow us sideways, and this will necessitate a correction.

In the southern part of England, the difference between the magnetic north and true north is plus 12 degrees, which means that if the course on the map is 254, the course to steer by the compass is 254 plus 12, or 266 degrees. So we write down MAGNETIC COURSE 266.

As the wind is blowing from 270 it is almost directly ahead and will therefore give us very little drift. However, we can add a couple of degrees to compensate for it. The COURSE TO STEER is, therefore, 268.

Now for our ground speed. We know that the aircraft will be cruising at 130 m.p.h., but as the wind is almost dead ahead and blowing at 10 m.p.h., the ground speed will be reduced to 120 m.p.h. We therefore write down GROUND SPEED 120.

Lastly, we must deal with the time factor. This is easy, for 216 miles at 120 m.p.h. will take us 107 minutes. We can now write down once again the vital information we shall need in the air:

COURSE TO STEER ...	268 degrees
TIME	107 minutes

As the weather is hazy, and because we take pride on our airmanship, we now go back to our maps and with the help of the ruler mark a cross on our pencilled track every twenty miles. We know that these points on the ground should turn up every ten minutes, as the ground speed is 120 m.p.h., or two miles every minute.

While the maps are still unfolded, we study the track once again and decide what other landmarks to look out for. In doubtful weather this is of the utmost importance, because we shall be flying so fast that once in the air we shall have little time to pore over the map and fly the aircraft at the same time. If you have a map of your own, you will be able to follow the next few paragraphs, if you have it open before you.

You will see that immediately after taking off we shall fly between the Staines reservoirs and then over Staines itself. After four miles we shall pass over Virginia Water, its curling shape quite unmistakable however thick the haze. After five minutes we shall cross a railway running through a big wood, and five minutes after that another railway, this time through open country.

Twenty minutes after take-off, we shall expect to see the little town of Litchfield below. We shall know it, because one minute before reaching it, we shall see on our right the first hill of any size to be encountered on the journey. In addition to this, we shall fly down the length of a strip of wood nearly three miles long. This also must be unmistakable.

In thirty minutes dead we shall cross the river Avon, and then after flying for eight minutes across a bare expanse of Salisbury Plain, another railway line, a river, and a large wood—all in the same minute. At forty-two minutes Zeals aerodrome should lie below, followed shortly by the level reaches of the Somerset plain. Individual features may be difficult to recognise here, but just before the hour, there'll be no mistaking the rising face of the new hills. We shall be flying over them for fully ten minutes, their first break coming in a valley with a railway running through it. On the other side of the valley is another one, and another railway. But we see from the map that it is single track. This will make it unmistakable. In seventy-five minutes we pass over the junction of two main lines at the village of Colebroke, Exeter is ten miles away on our left, and if the haze has cleared we ought to see it. At eighty-one minutes we are skirting Okehampton with a peak 2,000 feet high three miles to our left.

The ground on either hand is very high during this last stage of the flight, but the highest point crossed by our track is only 1,375 feet. We shall be over it five minutes after flying over Launceston, and ninety-five minutes out. If we keep at 1,500 feet we shall have ample margin. From this point—over a wild and desolate moor which appears to guard the Cornish peninsula—we should see the estuary of the river Camel with Padstow and our aerodrome on the further bank.

We can predict all this by "reading" the map. Years ago, when I made this journey for the first time, I remember carrying out the drill I have described,and I remember, too, how comforting it was to see the landmarks turning up one after the other. The weather was vile, but as I sat in the cockpit glancing from my watch to the earth immediately below (nothing else was visible) a railway, or a wood, or a river, grew out of the murk to a split second, as though a conjuror had waved a magic wand.

This is the secret of cross-country flying. It is also the reason why many fighter pilots are bad ferry pilots. The amateur relies on the homely rules of navigation; the service pilot, accustomed to radio bearings, is often lost without them.

The work on the ground has taken, perhaps twenty minutes. As soon as we are in the air, we realise how well-spent was the time, for though the sun is shining, the air is the colour of liquid butter and we can see no more than the field itself as we circle the airport. None of the usual landmarks are visible—the Heston gasometer, the reservoirs at Staines, and the loop of the River Thames beyond. Yet we climb with complete confidence to 1,500 feet, and then, flying over the top of the airport buildings, we set our course and our watch at the same moment.

There's no need to describe this journey, for the work so carefully done on the ground has, in effect, flown it already. Only a minor adjustment is required after the first twenty minutes. Instead of the town of Litchfield lying below, we have only reached the end of the long strip of wood four miles behind it. The wind is a little stronger than the "met." office had predicted, with the result that the time between the crosses on our maps is ten and a half minutes each instead of ten minutes. This is an adjustment we can take in our stride. The flight is completed without a moment's anxiety, and it was a flight which might have been "hair-raising" during its first half-hour, when the haze was so thick that had we not known what we were looking for, we should have felt like a man groping in a fog.

It is good practice to take out a map and plan flights from point to point, working out the details exactly as I have shown. Such an exercise will include a decision as to landmarks, and, perhaps, the choice of an alternative route which carries the track clear of high ground in the event of bad weather. It is possible in this way to become a competent navigator without ever flying at all.

It will, however, have been noticed that the effect of the wind on our flight from London to Cornwall was guessed rather than calculated. It was not necessary to do anything more in this instance, because it was virtually in our faces and quite light. If the wind is high and more on the beam, no such rough and ready methods will serve. For this reason, most pilots possess a calculator which, after the fashion of the mathematician's slide rule, gives him the answer to his problem.

At the same time all pilots should be able to work out the effect of the wind without any more apparatus than a ruler, a protractor, and a pair of dividers. This is how it is done:

FIRST: Decide on your air speed . . . say, 100 m.p.h.

SECOND: Write down the track you want to make good . . . say 025 degrees.

THIRD: Write down the wind speed and its direction . . . say, 30 m.p.h. from 045 degrees.

With this information we can draw a simple figure which will reveal the allowance to be made for the wind under these particular conditions. The procedure is as follows:

1. Draw two lines at right angles on a large sheet of paper to represent the points of the compass, north, south, east and west (see Fig. 48). The point where they intersect will be marked "A."
2. Set off the desired track AB to any convenient scale. As the aircraft is travelling at 100 m.p.h. through the

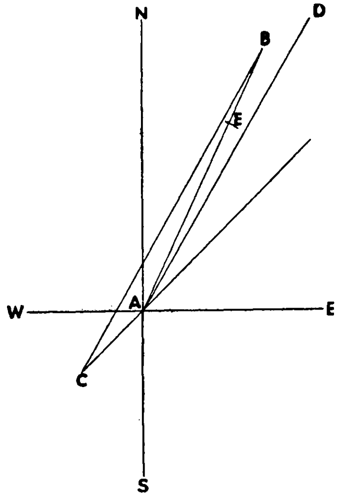

FIG. 48. Diagram illustrating method of calculating allowance to be made for the effect of wind.

air, we will make the line 10 inches long, representing 10 miles to the inch.

3. Set off the wind to the same scale and continue it through the point A. As it is blowing at 30 m.p.h., the line will be 3 inches long. This is shown in the figure as AC.
4. Take a ruler and join C and B. The line CB is the course to steer to make good a track of 025 in this particular wind. For the convenience of measuring the angle we complete the parallelogram BCAD and measure the angle NAD. This is 30 degrees. Our true course (in aviation language) is accordingly 030.
5. To find our ground speed, we now take the dividers and open them to 10 inches (the air speed). With the centre at C we describe a circle, and where it cuts the track AB we mark the point E. We now measure AE, which will be found to be 7.2 inches, which by our scale represents 72 miles. The ground speed is 72 m.p.h.

Any wind and any course may be dealt with in the same way. The skilled navigator can draw in the conditions and take his measurements in three minutes. Practice this, and don't be satisfied until you have the answers within this period.

So much for airmanship as it applies to a cross-country flight. Other elementary rules have already been mentioned, but they are so important that they may be repeated here, together with some others which every man or woman who is taking up flying should learn by heart.

Before Take-off

Check your cockpit item by item and refuse to take off unless every instrument is giving its proper reading. Fasten the safety harness so tight that it holds you right back in your seat. Watch for the green light of the control officer before opening the throttle, or if there is no ground control, make sure that the sky behind you is empty. It is unpleasant to have anyone land on top of you.

Before Landing

Make a circuit of the aerodrome at 1,000 feet. If the way is clear, carry out a normal approach as taught by your instructor. (If this seems obvious, it may be mentioned that careless pilots have been known to creep in low, or dive in from an excessive height, and that many a collision has resulted with another aircraft.)

During Flight

Do not enter cloud until you have had dual instruction in blind flying. If the weather deteriorates, turn back before, and not after, you lose yourself. In this connection, never fly up a valley if there is the slightest risk of the weather closing in behind you and ahead. More accidents have probably been caused by this mistake alone than any other.

On the Ground

Never touch a propeller, or allow anyone else to do so, without personally checking that the switches are "off."

Learn the local rules of your club, or airport, and never break them. Make the same resolution about "shooting a line" as you did at your gliding club. The man you are talking to is probably a pilot with a thousand hours of aerobatics behind him !

CHAPTER EIGHT

FLYING AND THE HUMAN BODY

The effect of the air on the senses—blackout, redout—high altitude flying—change of air pressure—the effect of blind flying on the senses—night vision—the effect of high speeds—flying clothes.

THE story of the air has already been told in this book . . . how the great air currents are generated, and how they may be used by the glider pilot. We come now, in this last chapter, to a brief survey of the effect of the air on the human body—how altitude will cause unconsciousness, and turns made at high speed, "blackout." These, and kindred matters, should be appreciated by all who take up flying. One day they will meet them in the sky, and it is essential that they know how to deal with them.

"BLACKOUT" AND "REDOUT"

Many years ago a R.A.F. Gladiator came to the station where I was serving. Such was the reputation of this old-time fighter for sweetness of control that I would not rest until I had flown it. Eventually, the officer to whom it belonged lent it to me, and I took it up to 6,000 feet to see what it could do. Up to that time I had never flown a fighter type of aircraft, so that when I decided that I would loop, I opened the throttle, waited till the A.S.I. showed 250 m.p.h., and then pulled hard back on the stick. The first quarter of the loop was excellent. The nose rose higher and higher and I seemed to be rocketing vertically upwards at a terrific speed. Unfortunately, the world appeared to grow grey at the same time, as though the light was draining out of the sky, and a terrific pressure was pushing me down into the seat. Before I could do anything about it, the grey turned to complete blackness, and I lost consciousness, to wake up a few seconds later. The first thing I saw was the ground. I was was looking up at it. Instinct and alarm demanded that I immediately right the machine, with the result that I did a roll off the top of what otherwise would have been a very tight loop.

I had probably subjected myself to at least 7G, which means that owing to centrifugal force, my weight had been increased from twelve to eighty-four stones—when my blood would be heavier than molten iron. The average pilot can stand about 5G for five seconds without passing out. This would be achieved by flying an aircraft at 200 m.p.h. and trying to make a turn within the same radius as one would make a normal turn in a training aircraft.

Any change in direction increases "G," and I have mentioned earlier how its effect is to put up the wing loading of the aircraft. A machine which weighs one ton would weigh ten tons in the course of a manoeuvre which applied 10G, and under such a strain, the wings of most aircraft would collapse. The "G" figure which it is possible to apply to any particular machine without structural failure is known as its safety factor. This is usually in the neighbourhood of eight for gliders, and may be anything in the case of power aircraft, depending upon the purpose for which they were designed. It is, for instance, virtually impossible to "pull the wings off" a fighter, because the pilot will "blackout" long before the danger figure is reached. As soon as he loses consciousness, his hands fall off the controls and the turning movement is arrested.

There is another kind of "G" which is more sinister. It is called "negative G," as opposed to the "positive G" of which we have been speaking. This is the result of a reverse movement of the aircraft, such as is found when the pilot suddenly pushes forward the stick while flying straight and level. The blood rushes to the pilot's head and causes "red-out" instead of "blackout." The aerobatic known as the "bunt" (an outside loop) can cause it in excessive measure, and permanent injury may be done to the brain if it is continued for more than a few seconds. The manner in which the average pilot meets it for the first time is the result of a stall off the top of a loop which develops into an inverted spin. If the normal recovery methods are applied, there is no risk.

High Altitude Flying

Man has climbed to a height of over 28,000 feet without the aid of oxygen on the slopes of Mount Everest. If you went up to the same height in an aeroplane you would lose consciousness in about ten minutes, and after half an hour it is possible that you would be dead. In the case of the mountaineers, the climb was made over a period of weeks and their bodies had become acclimatised to the lack of oxygen and the low pressure of great heights. The airman has no such chance.

In most flying services, it is a rule that oxygen shall be used over 15,000 feet. But at even lower levels there are often insidious changes in a pilot's efficiency which he does not notice. I remember the difficulty I had after flying for some while at 12,000 feet, in concentrating sufficiently to change to a fresh course given me by the navigator. The physical and mental effort of turning the aircraft through 180 degrees was almost too much. A more striking example of the same effect occurred on a pamphlet raid over Germany in which the crew disconnected their oxygen masks in order to unload their pamphlets. They soon became anoxic, and flopped down into their seats as though they were drunk. Eventually they roused themselves and threw out the pamphlets without removing them from their parcel. The parcel landed in Southampton, to which by that time they had returned.

All service pilots are tested in a special pressure chamber for their reactions to great heights. At 30,000 feet they rarely remain conscious for longer than three minutes. The experience of "passing out" is not in the least unpleasant. At one moment you feel perfectly all right . . . the next you are "asleep." When I took this test myself, I could not believe that I had been unconscious. There had been no break in my thoughts which I could remember. The danger to the airman whose oxygen supply fails without him noticing it is obvious.

Change of Air Pressure

A subsidiary effect of altitude flying is the change of air pressure, both on the way up and coming down. As the air is thickest nearest the ground, the effects are more marked in the 10,000 feet next to the earth. A fighter pilot told me that during the Battle of Britain, the greatest strain to which he had been subjected was the pressure changes through descending from 25,000 feet, refuelling the aircraft, and going up again. His ear drums had felt like bursting, and long before the end of each day he was virtually deaf and had a blinding headache.

The descent from high altitude to low altitude has a much more marked effect than from low to high. This is because the valves of the human ear, which have the task of equalising the pressure inside with the pressure outside, work more efficiently in one direction than the other. Even the man who is learning to fly will experience this phenomenon before he takes his "A" licence. A rapid descent from 3,000 feet will make his ears buzz, and perhaps cause temporary deafness. Dive bomber pilots are encouraged to shout or sing while making their dives. This is a help. Personally, I "swallow" air in rapid gulps—which is equally effective.

The Effect of Blind Flight on the Senses

As soon as a pilot loses sight of the fixed point upon which he is flying his senses of balance will desert him one by one, until after a minute or two, he will not know whether he is on his head or his heels. Normally, the horizon is the object by which he flies, but equally well it may be a cloud, the sun shining through the haze, a light on the ground, or even a star. All that matters is that a fixed point should act as a peg on which to hang his senses.

The eye is the master instrument in the pilot's personal cockpit. Take it away, and the other two senses—ears and the muscle sense—will deceive him. It is easy to test this with a revolving piano stool. If the pilot is blindfolded and turned at a constant speed to the left, he will at first correctly interpret what is happening. But if the rate of turn is now slowed down, he will be convinced that the chair has stopped and begun revolving to the right. Alternatively, he will be convinced that all movement has ceased if the rate of turn is continued in the original direction for more than twenty seconds, in other words, without the master sense of the eye, the remaining senses are not only valueless, but dangerous, since incorrect impressions are transmitted to the brain.

Human beings are not peculiar in this shortcoming. Pigeons have been blindfolded under test conditions and they invariably set their wings in a glide and land. Nor has any bird ever been seen flying blind in cloud or dense fog—in spite of the much higher development of their senses of balance.

For this reason it is essential that the pilot should place implicit faith in his instruments. It is not an easy thing to do when he is certain that he is turning to the left when his instruments say that he is turning to the right. Sometimes an added complication is what may be called partial visibility. I remember one such occasion well. I was flying over the sea in thick haze. There was no dividing line between the water and the sky, and both were exactly the same colour. I was trying to fly by using a combination of my eyes and the instruments, with the result that I suddenly saw a ship in what I thought to be the sky. The moral is, "never mix the two." Make up your mind that the conditions warrant instrument flying and then ignore your private convictions.

Night Vision

In the early stages of his flying career a pilot is unlikely to have any use for his "night vision." But there is no reason why he should not understand it and, by practice, improve it.

There is a part of the eye set aside for "seeing" in the dark. It is 10,000 times more sensitive than the part which is used by day, but before it can be brought into use the eyes must become "night adapted." This means that they must remain in almost complete darkness for at least half an hour. The effect of this is seen after entering a darkened cinema, when at first one stumbles blindly over people's feet, but later can see well.

The part of the eye which is now operating lies to one side of the sensitive surface which receives the light rays. The result is that at night the best vision is obtained by looking a little to one side of the desired object. Proof of this can be had on any starlit night. If you focus your eyes on a particular star, you will see many others around it, but if you now try to focus one of these directly, it will disappear. Alternatively, if you look at a particular point in the heavens, the stars round this point will look brighter. Shift your gaze, and these stars will dim, while the original point will now look brighter.

The difference between good and bad night vision is a matter of training. Night fighter pilots become experts at interpreting the very dim shadows which they see. So do wildfowlers who flight duck before dawn. They see the faintest of outlines against the sky, swing their gun on to it and fire, all in the same instant.

You ought to be able to see a bomber on a starlit night from half a mile, and if there is a full moon but no cloud, from three-quarters of a mile. On the other hand, if there is a floor of cloud and you are a fighter pilot looking down from above, you will see it over a mile away. Alternatively, you will need to be within a hundred yards before you see it if you are looking for it against the land, even on a bright starlit night. You will not even achieve these results until you train your eyes.

The quality of night vision is destroyed within sixty seconds of entering a brightly-lit room. You will have noticed how dazzling the light at first appears. This is your night vision giving you its ultra-sensitive services. In a moment, nature provides an opaque coating to protect the sensitive cells, and the light fades as the day vision takes over.

The Effect of High Speeds

Although I have never flown a jet-propelled aeroplane, I have frequently tried to give myself a thrill by exceeding 400 m.p.h. in a standard type of fighter. I have never succeeded. Four hundred miles an hour feels no faster than sixty—unless you are very close to the ground. A fly buzzing round in the cockpit is unaware of movement—though it may in fact be travelling across the surface of the earth at six miles a minute.

There is no limit to the speed at which men may fly. The effect of it can only be felt when direction is changed.

Flying Clothes

Glider pilots are more prone to make mistakes in the matter of their clothing than power pilots. It is always cold in the open cockpit of an aeroplane, and the new pilot soon discovers it. But the glider pilot flies so slowly, and usually so close to the earth, that the clothes he wore on the ground afford sufficient protection. Then comes the day when he rides to the clouds on a thermal and remembers too late that the temperature is dropping five degrees for every thousand feet of extra height. I have found myself in a temperature below freezing point in an open summer shirt and without a coat.

Flying clothes can therefore be divided under two headings—those required for power flight, and those for soaring. In an aeroplane with an open cockpit I prefer a standard Sidcot suit and a pair of leather gauntlets. In a glider, I think that a couple of sweaters with a windproof golf jacket are the best equipment. On the feet, I prefer tennis shoes a size too big with two pairs of socks pulled up over the trousers. Heavy shoes or boots seem to detract from the sensitive touch which I have always felt is necessary on the rudder bar of a sailplane. On some days you will admittedly perspire—but I find this preferable to freezing on those occasions when a really good flight is in prospect.

BIBLIOGRAPHY

AIR MINISTRY. *Meteorology for Aviators.* By R. C. Sutcliffe. London. (H.M. Stationery Office).

AIR TRAINING MANUAL: *A Practical Guide to Aero-Engines, Aircraft Construction, Air Navigation, etc.* London. (Odhams).

ALLAN, W. J. D. *Allan's Guide to the Pilot's "A" Licence.* London. (Allen and Unwin).

BROWNE, H. F. *Aeroplane Flight : An Introduction to Aerodynamics.* London. (Longmans).

CARR, C. F. *Gliding and Motorless Flight.* London. (Pitman).

FLIGHT. *Flight Handbook :A Manual of Aeronautical Theory and Practice.* London. (*Flight*).

HORSLEY, T. *Soaring Flight.* London. (Eyre & Spottiswoode).

JORDANOFF, A. *Safety in Flight.* New York. (Funk & Wagnalls).

JORDANOFF, A. *Your Wings.* New York. (Funk & Wagnalls).

NEEDHAM, C. H. L. *Sailplanes : their Design, Construction and Pilotage.* London. (Chapman).

PAGE, V. W. *Henley's ABC of Gliding and Sailflying.* London. (Chapman).

PATON, J. *Meteorology for the Airman.* London. (University of London Press).

PRESTON, R. L. *How to become an Air Pilot.* London. (Sampson Low).

SCHOFIELD, H. M. and JOHNS, W. E. *The Pictorial Flying Course.* London. (John Hamilton).

TANGYE, N. *Teach Yourself to Fly.* London. (English Universities Press).

VEALE, S. E. *Guide to Flying.* London. (*The Aeroplane*).

WIMPERIS, H. E. *Aviation.* London. (Oxford University Press).

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BRITISH GLIDING CLUBS

Club or Organisation	*Secretary*	*Address*
BRITISH GLIDING ASSOCIATION	E. H. Spence (*Acting*)	119 Piccadilly, London, W.1

1939 B.G.A. CLUBS STILL IN EXISTENCE

CAMBRIDGE UNIVERSITY GLIDING CLUB	F. J. Cripwell ..	Pembroke College, Cambridge
CHANNEL GLIDING CLUB	F. G. Whitnall..	16 Cheriton High Street, Folkestone
DERBYSHIRE AND LANCASHIRE GLIDING CLUB..	B. Thomas ..	87 Fargate, Sheffield, 1
DORSET GLIDING CLUB..	L. A. Lansdown	The Portman Arms Hotel East Chinnock, Yeovil, Somerset
FURNESS GLIDING CLUB..	J. C. Redshaw..	12 Rusland Avenue, Barrow-in-Furness
KENT GLIDING CLUB ..	Mrs. E. O'Neil Haddock	Lenhurst, Harrietsham, Kent
LONDON GLIDING CLUB..	A. Sweet ..	6 Roland Gardens, S.W.7
MIDLAND GLIDING CLUB	F. G. Batty ..	2 Lombard Street West, West Bromwich
NEWCASTLE GLIDING CLUB	A. P. Miller ..	25 Holme Avenue, Walkerville, Newcastle-on-Tyne, 6
NORFOLK AND NORWICH GLIDING CLUB	A. A. Rice ..	5 Opie Street, Norwich
OXFORD UNIVERSITY GLIDING CLUB	Miss B. M. Nicklin	532 Banbury Road, Oxford
SCOTTISH GLIDING UNION	R. B. Rogerson	59 Carmyle Avenue, Glasgow, C.2
SOUTHDOWN GLIDING CLUB	B. G. Stevens ..	Southerlea, Meadow Close, Hove
SURREY GLIDING CLUB..	A. Dukinfield Jones	23 Rose Hill, Dorking, Surrey
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CROYDON GLIDING CLUB	L. Martin ..	74 Lewin Road, S.W.16
HULL GLIDING CLUB ..	W. E. Walker ..	198 Alliance Avenue, Newington, Hull
NORTHERN GLIDING CLUB (Formerly Rochdale)	F. Haworth ..	30 Fernhill Drive, Stackstead, Bacup, Lancs.
PORTSMOUTH AND SOUTH HANTS. GLIDING CLUB	A. Fripps ..	The Barnhouse, Broadwork Road, Rustington, Sussex
STANDARD TELEPHONES AND CABLES GLIDING CLUB	A. Evison ..	Standard Telephones and Cables Athletic Club, Gliding Section, North Woolwich, E.16
ULSTER GLIDING CLUB ..	J. Mackie ..	James Mackie & Sons, Ltd., Belfast

CLUBS FORMED SINCE 1939

LEICESTER GLIDING CLUB	J. C. Rice ..	Park Works, Blaby, near Leicester
AEROTECH FLYING CLUB No. 1	W. A. O'Higgins	17 Brentvale Avenue, Southall, Middlesex
M. V. BARTON GLIDING CLUB	M. Rhodes ..	Metropolitan-Vickers Ltd., Barton Dock Road, Eccles, Lancs.

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